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Chromang	307	Black	.....
Chromend 19/9 Cb	347	Yellow	Blue
Chromend K-Mo	316	Yellow	White
Chromend K-Mo-Cb	316 + Cb	Yellow	Green
Chromend 18/8 Mo	317	Yellow	Brown
Chromend KS	302 + B	Yellow	Red
Stainlend K	308	Black	.....
Chromend HC	309	Black	White
Chromend 25/12 Cb	309 + Cb	Black	Blue
Stainlend HC	309	Red	White
Chromend HCN	310	Red	.....
Chromend 25/20 Cb	310 + Cb	Red	Blue
Chromend 25/20 Mo	310 + Mo	Green	Light Green
Chromend HN	311	Green	Brown
Chromend 8/18	325	Green	Yellow
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Chromend 29/9	312	Green	.....
Chromend 15/35	330	Green	Blue
Chromend 13/60	.....	Green	Orange
Chromend 13/75	Inconel	Green	White
Chromend 15/85	.....	Light Green	White
Chromend 20/80	.....	Black	Orange
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Chromend 2M	2% Cr.—Mo.	.....	.....
Manganend 2M(S)	Special	Grey	Blue
Chromend 5M	502	Grey	Brown
Chromend 12	410	Grey	Green
Chromend 16	430	Grey	Red
Chromend 18	442	Grey	Yellow
Chromend 28	446	Orange	Blue
Mixend	Monel	Orange	.....
Reformend	M. S. for C. I.	Orange	Red
Manganend 13	13% Mn. Steel	.....	.....
Bronzend E	Everdur	.....	.....
Bronzend P	Phos. Bronze	.....	.....
Carend	Mild Steel	.....	.....

Note:—Type numbers are those of the American Iron and Steel Institute. The weld metal analysis nearest to that specified by A.I.S.T. is the one here used for reference.

NOTE: Where the grade name indicates analysis, the first figure is the % Chromium and the second figure is the % Nickel. (For instance, Chromend 20/80 is 20% Cr. and 80% Ni.)

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Moline, Ill......Machinery & Welder Corp.
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San Diego, Calif......Victor Equipment Co.
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PETROLEUM REFINER

SPECIALIZED FOR THE OIL REFINING INDUSTRY, INCLUDING PETRO-CHEMICAL ENGINEERING, PETROLEUM SYNTHETICS AND NATURAL GASOLINE

September, 1943
Vol. 22, No. 9

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GRADY TRIPLETT
Editor

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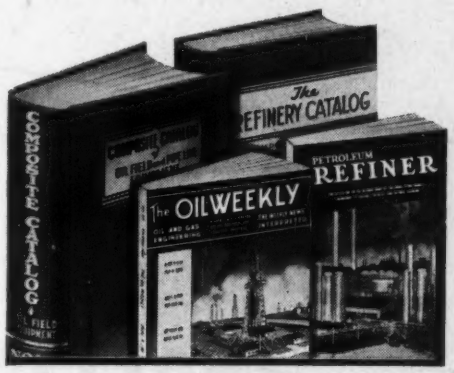

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CONTROLLING FACTORS in Petro-chemistry

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PETROLEUM
REFINER

SPECIALIZED FOR THE OIL REFINING INDUSTRY, INCLUDING PETRO-CHEMICAL ENGINEERING, PETROLEUM SYNTHETICS AND NATURAL GASOLINE

A GULF PUBLISHING COMPANY PUBLICATION

THE LOOK BOX

DESPITE the furore that attends proposals to turn coal as a source of motor fuel, it will be natural gas that first supplements crude oil in the United States. Known reserves of the two are sufficient to supply the nation for a half century at current rates of consumption. Processes are at hand for converting natural gas to liquid products.

Gas Comes Before Coal

Coal has been making the news but natural gas will be first to make the gasoline. There is something spectacular in the members of a congressional committee riding to the scene of their hearing in cars powered by fuel from coal. That and other newsworthy events left little space for the testimony of authorities such as Gustav Egloff, Bruce K. Brown and R. P. Russell, who placed natural gas first in their list of raw materials that will supplement crude oil. In turn came oil sands, shale and finally coal.

That coal can be converted to liquids identical with those from petroleum is well established. That it will be more difficult and more expensive to process is accepted. Coal and the knowledge of how to process it are reassuring. Along with the other raw materials and what can be done with them, it adds up to prospect of ample liquid fuel.

Working with natural gas will require adaptation of the established Fischer-Tropsch process. Like many others it is of European origin and had its development where crude oil was not plentiful, accordingly it has been given limited attention in the United States. Either natural gas or blue water (artificial) gas can be converted to motor fuel, waxes, chemicals and synthetic lubricants by adaptations of this process.

This process is one of low temperatures and high pressures, the reverse of the recent catalytic trend, wherein pressures have been lower with moderate temperatures. Another fundamental difference in processing natural gas would be in feeding it into plants, since compressors rather than pumps would be essential. Instead of treating products near the finishing stage, impurities could be removed from the raw material.

Just now there is a consistent searching of the German literature for information on the Fisher-Tropsch process as well as other contributions to the processing of natural gas. The industry's research organizations as well as governmental agencies are engaged in this study.

This issue of PETROLEUM REFINER offers a translation from the German literature as a part of this search for information. Other contributions of similar nature will be offered in succeeding months.

Results from this combination of study will be a development similar to those resulting from study of hydrogenation. So many new processes will result that the primary process will be overshadowed. The Fischer-Tropsch process is simply a starting point in the conversion of natural gas into the ramification of fuels and chemicals that can be had from hydrogen and carbon.

Meanwhile the men and women of the petroleum industry should placate any fear of immediate oil shortage by pointing out discoveries are still possible and that oil can be imported into the United

States just as it is now being sent away. Exhaustion of the world's crude oil is too far away for worries of this or the next generation.

It is comforting to know that natural gas is available and that the industry knows how to use it.

Women At Work

FOR all its fanfare, adaptation of the feminine worker to refining is proving limited. All of this is normal and should have been expected. In a few instances personnel departments strove for the impression of successful introduction of women into each phase of refinery operation. There have been no admissions of the fallacy of these programs, although proper restrictions have been accepted in most cases.

Experience is proving what calculation should have dictated—that women are not capable of performing all the duties involved in operating a modern refining plant.

The latest effort to expand the role of feminine influence beyond actuality comes from the Petroleum Administration for War. At its suggestion the Bureau of Labor Statistics made a study of women workers in refining, finding 2,627 women workers out of 27,646 in 74 plants.

This has been offered as evidence that 10 percent of the workers in refining plants are women. The fallacy of this conclusion is evident in a close study of activities. In the first place it is likely that the census was made in plants of larger oil companies, whose facilities for training women workers are such that their total will be higher than for the industry as a whole. For this reason it is doubtful that 10 percent of the workers in refining plants are women.

It is from a scrutiny of activity classifications, however, that fallacies are evident. Of the 2,627 women working in the 74 plants, 1,156 are in offices, an activity to which they came long before war made its drain on manpower. The survey really showed 1,471 women to be working in these plants, 5.3 percent of the total workers. Even this total includes 477 feminine workers in laboratories. In reality fewer than 1,000 of the 27,646 persons working in the 74 plants are women whose duties have to do with operation and maintenance of refining equipment.

Perhaps this is a proper ratio. Women are not suited to the rigors of much that is required in keeping a modern plant operating. This is not to their discredit. It is to their credit that they have adapted themselves to the point where they can become 5.3 percent of the total of workers in 74 refining plants.

Another Billion

MERE mention of another billion dollars should cause no consternation in this day, still the charge that efforts to increase the price of crude oil will result in a "steal of $1,400,000" has brought on a hunt for some basis for the figure. The charge was made by Boris Shiskin of the staff of the CIO, who was introduced as a member of a sub-committee of the Office of Price Administration.

But simple arithmetic fails to justify the charge. If crude oil production in the United States should come to an average of 4,500,000 barrels per day, the year will see the record production of 1,642,500,000 barrels taken from the ground this year. It should be admitted that such an average seems impossible for this year.

Even an increase of 50 cents per barrel on such a total will not bring the $1,400,000,000 as calculated by Shiskin and his associates, also representatives of other labor organizations. Since it is impossible to determine what effect the increase would have on retail prices, calculating the effect on the public purse is impossible.

One of the pointed rejoinders from the petroleum industry came from Charles P. McGaha, president of the National Stripper Well Association, who observed:

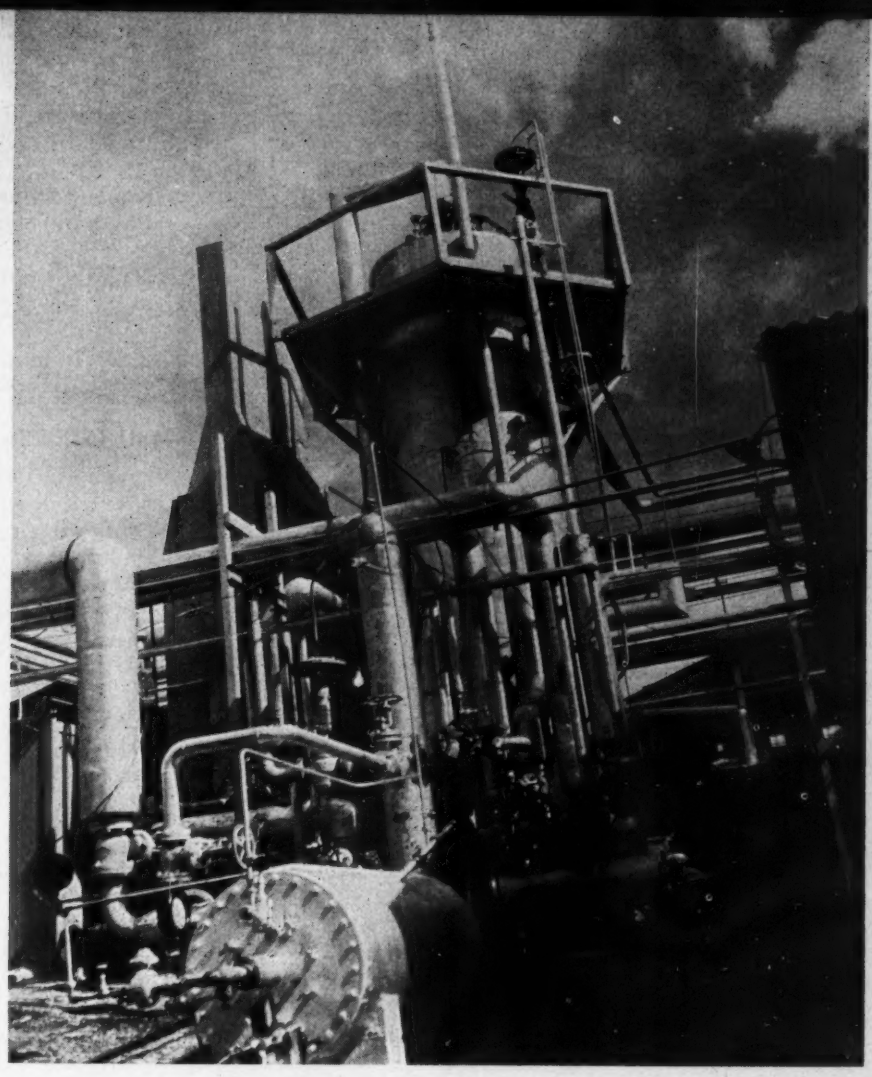
"It is well worth noting that the three men who made this vicious attack—Messrs. Shiskin, Luhrsen and Walsh—are representatives of labor organizations on an OPA advisory committee. The index price of oil today stands at 61 percent of parity. The index price of all other commodities stands at 104 percent of parity and labor itself stands at 170 percent of parity. If any "steal" has been put over on the American public, it should be obvious who is in possession of the loot."

Looking at Patents

ATTITUDE of the National Patent Planning Commission toward the United States patent system is refreshing when compared with the attitude of some federal officials. The report of this group leaves no doubt of its faith in the soundness of the patent system. Along with this it recognizes the weaknesses of the system. It recommends changes.

Its report was given The President earlier in the year and has been transmitted to Congress. It is to be hoped that its recommendations are considered along with the proposals, which would alter the basic concept of a patent being property.

That the patent laws of the United States can be improved is logical. The commission, headed by Charles F. Kettering, recognized this prospect and made definite recommendations. The attitude is more hopeful than that of the few who look upon a patent as inherently a thing of evil.



Furnace and catalyst case of Houdry adiabatic process, semi-commercial scale, at a plant of Sun Oil Company.

Production of Hydrocarbons For Aviation Motor Fuels

M. VAN WINKLE
The Pennsylvania State College

In 1930 the octane rating of the highest grade of aviation gasoline was about 87. The United States Army Air Forces specified this grade for use as a first-line fuel while most commercial aviation was using fuel averaging 73-octane number. The aviation gasolines increased in antiknock rating until 1935 when a small quantity (around 8000 barrels) of 100-octane fuel was made for the Army Air Forces for experimental purposes. In a very few years the Army was using this grade of aviation gasoline for a first-line fuel and it had been adopted by many commercial airlines.

In 1941 it was estimated[1] that 12 million barrels of the 100-octane-grade aviation gasoline was produced. In 1942 Secretary Ickes asked for a production of 180,000 barrels per day, or an annual production of 64 million barrels. Latest estimates of the requirements for this grade of fuel run from 70 to 90 million barrels annually.

This enormous demand for high-quality aviation gasoline has been primarily responsible for the development of a new hydrocarbon-chemical industry within the refining industry, whose purpose is to produce hydrocarbons of high antiknock characteristics which are necessary blending agents in the manufacture of 100-octane aviation gasoline.

Specifications for Aviation Gasoline

Many rigid specifications have been established to control the quality of 100-octane aviation gasoline. Many of the individual specifications are subject to frequent modification to insure better quality or greater availability and as the result, any list given at a particular time may be incorrect a short time

TABLE 1

Specifications on 100-Octane Aviation Gasoline[2]

	100-Octane Grade
Calorific value, net, Btu/lb., min.	18,700
Color, Saybolt, min. (undyed)	25
Color (dyed)	blue
Corrosion, copper dish	none
Corrosion, copper strip	none
Distillation, ASTM:	
10 percent evaporated, °F. max.	158
50 percent evaporated, °F. max.	212
90 percent evaporated, °F. max.	257
10 percent plus 50 percent evaporated, °F. min.	307
Recovery, percent, min.	97.0
Residue, percent, max.	1.5
Loss, percent, max.	1.5
Acidity of residue	none
Freezing point, °F. max.	−76
Gum, accelerated, mg/100 ml, max.	6.0
Gum inhibitor, lb./5000 gal. max.	1.0
Octane number, ASTM-CFR Aviation Method, min.	100
Sulfur, percent, max.	0.05
Tetraethyl lead, cc/gal., max.	3.0
Vapor pressure, Reid, max.	7.0
Water miscibility, max.	±2.0 ml.

later. In addition, war secrecy regulations prevent publication of the latest specifications on aviation gasolines used by the armed forces. However, the commercial specifications found in Table 1 will serve to indicate the quality of 100-octane aviation gasoline.

Composition of 100-Octane Fuel

A study of the specifications for the 100-octane-grade aviation gasoline indicates that such a fuel rarely can be made by following ordinary refining procedures. The narrow boiling range, high stability requirements, and high octane number in conjunction with a low permissible tetraethyl lead content of the finished product prohibit the use of simple fractionation of straight-run and cracked gasolines to the desired boiling range and "leading" to the required octane number. Therefore, it is necessary to use blending materials having suitable characteristics, particularly high-blending octane numbers and lead susceptibilities, to produce the high qualities necessary in 100-octane aviation gasoline.

The first fuel of this grade was composed of a blend of straight-run naphtha, isooctane, isopentane, and tetraethyl lead. As new processes were developed, different types of base stocks as well as high-octane blending components came into use and the composition of 100-octane aviation gasoline varied greatly from that of the first type produced. Several of the possible compositions are shown in Table 2.

Although the compositions shown in Table 2 are given within relatively wide ranges, there are undoubtedly exceptions. They, however, serve to give a general idea as to the type and quantity of the constituting materials used in present-day practice in 100-octane aviation fuel.

The high-octane blending components are isopentane, neohexane, isooctanes, substituted benzenes, and benzene. These are compounds or relatively pure mixtures of compounds which are not all available in the necessary quantities from physical separation methods applied to petroleum. Isopentane is recoverable from fractionation of natural gasolines and crude oils and benzene and some benzene derivatives are available from the destructive distillation of coal. Most of the high-octane blending components, however, must be produced synthetically by means of hydrocarbon-conversion processes in order to insure their availiability in the quantities needed.

TABLE 2

Typical Compositions of 100-Octane-Grade Aviation Gasoline[3]

	1	2	3	4	5	6
Straight-run naphtha, 65-80 O. N., percent	30-50	30-50	.....	30-40	30-50	30-50
Conversion naphtha, 76-82 O. N., percent	.....	.....	40-60	30-40	.....	.....
Isopentane, 90-95 O. N., percent	10-15	10-15	10-15	10-15	10-15	10-15
Neohexane, 90-95 O. N., percent	.....	20-30	.....	.....	.....	.....
Isooctanes,* 90-100 O. N., percent	40-60	20-30	30-40	30-40	30-50	20-30
Substituted benzenes,† 90-100 O. N., percent	.....	.....	.....	.....	.....	5-20
Benzene, 90-100 O. N., percent	.....	.....	.....	.....	10-15	.....
Tetraethyl lead, cc./gal., max.	3.0	3.0	3.0	3.0	3.0	3.0
Gum inhibitor, lb/5000 gal., max.	1.0	1.0	1.0	1.0	1.0	1.0

* Alkylates, alkylate gasolines, hydrogenated polymers. † Cumene, isobutyl benzene, etc.

Methods of Producing High-Octane Hydrocarbons

There are two principal methods used in the manufacture of high-octane hydrocarbons. One involves the combination of suitable small hydrocarbon molecules to form larger ones having satisfactory fuel characteristics, and the other involves the rearrangement of the structure of larger hydrocarbon molecules without changing their size. Polymerization and alkylation are examples of the first method and isomerization, aromatization, and cyclization are examples of the second.

Table 3 lists the methods used in the manufacture of high-octane hydrocarbons.

TABLE 3

Process for the Manufacture of High-Octane Hydrocarbons[3]

PROCESS	Molecular Change	Charge Materials	Direct Products	Finished Products
Catalytic polymerization	Size and structure	butene isobutene propene	isooctenes isoheptenes	isooctanes isoheptanes
Catalytic alkylation	Size and structure	isobutane butene propene benzene	isooctanes isoheptanes cumene	isooctanes isoheptanes cumene
Thermal alkylation	Size and structure	ethene isobutane	neohexane	neohexane
Catalytic isomerization	Structural	pentane hexane heptane octane	isopentane isohexane isoheptane isooctane	isopentane isohexane isoheptane isooctane
Catalytic aromatization	Structural	hexane hexene heptane octane nonane	benzene benzene toluene ethyl benzene propyl benzene	benzene or substituted benzene toluene ethyl benzene propyl benzene
Catalytic cyclization	Structural	pentane hexane	cyclopentane cyclohexane	cyclopentane cyclohexane

The charge materials necessary for these conversion processes (Table 3) are listed as follows:

Paraffins
- butane
- isobutane
- pentane
- hexane
- heptane
- octane
- nonane

Olefins
- propene
- butene
- isobutene

Aromatics
- benzene

The paraffins with the exception of isobutane are available from crude oil and natural gasoline in sufficient quantity for process demands; the olefins are available from cracking processes although in some

This Houdry catalytic unit was thus described when the picture was provided by Sun Oil Company, "since America entered the war has contributed more to the production of catalytic aviation gasoline base stock than any other plant in the world."

plants the necessary amounts of the right kind of olefins are lacking; and, benzene is available in large quantities from destructive distillation of coal. The charge materials of which there are insufficient quantities are produced by means of conversion processes. For example, catalytic isomerization of butane produces isobutane, catalytic dehydrogenation of butane and isobutane produces butenes and isobutene, and aromatization of hexane, heptane, etc., produces benzene and other aromatics.

In addition to the processes necessary for the production of suitable charge materials, it is further necessary to process the olefinic product obtained from polymerization to convert it into a saturated isoparaffin. This is accomplished by hydrogenation.

One or all of these processing methods may be used in a particular plant engaged in the manufacture of 100-octane gasoline. The number and type in use depends to a great extent on the plants' capacity for the production of suitable charge materials in the quantities needed and the basic conversion methods used in the manufacture of high-octane hydrocarbons.

Commercial Processes Utilized in the Manufacture of High-Octane Hydrocarbons

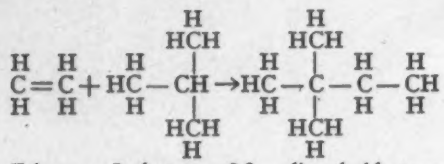
During the last 10 years and particularly during the last 5 years, the development of all types of commercial hydrocarbon-conversion processes has been taking place rapidly. As a result the refining industry has been able to supply at a relatively low cost the large amounts of high-octane hydrocarbons needed for the much-expanded aviation-fuel program. Although the majority of the productive capacity is achieved by the operation of relatively few processes (in regard to type) new ones are being put into operation at frequent intervals. Whether or not all of these will survive after the war is over is a question which is difficult to answer and which will depend upon the economic adaptation of the processes to the type and quantity of fuel demands in the post-war period.

The processes which are being utilized commercially in the manufacture of high-octane hydrocarbons are: (1) alkylation, (2) isomerization and (3) polymerization. Accessory processes for the preparation of charge stocks or the treatment of products from the conversion are: (1) dehydrogenation, (2) isomerization and (3) hydrogenation.

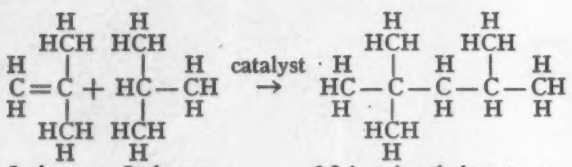
Alkylation

One of the most important process types for the production of high-octane hydrocarbons is that of

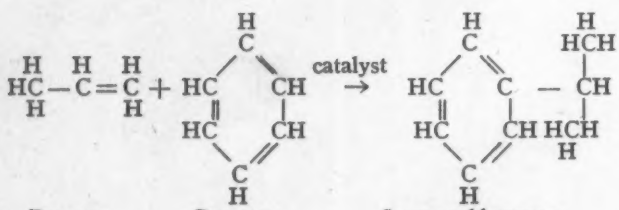
alkylation. It may be defined as the union of an olefinic hydrocarbon with an isoparaffinic or aromatic hydrocarbon to form an isoparaffin of higher molecular weight or an alkyl benzene. Sample reactions are shown as follows:



Ethene Isobutane 2,2—dimethyl butane (Neohexane)



Isobutene Isobutane 2,2,4—trimethyl pentane (isooctane)



Propene Benzene Isopropyl benzene (cumene)

These reactions may be conducted with or without catalysts.

Three commercial alkylation processes are in operation; the Sulfuric Acid process[4,5], the Hydrofluoric Acid process[6,7], and the Thermal Alkylation[8] or Neohexane process. Complete data on all of these processes have not been reported and Table 4 merely gives a brief comparison.

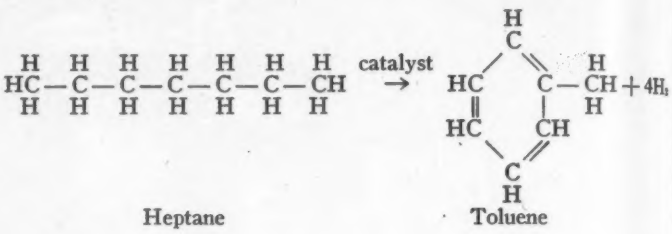
The catalytic processes produce high yields of alkylate containing large percentages of isooctanes and having octane numbers ranging from 88 to 95. The neohexane process produces a relatively high yield of alkylate fraction which has an octane number ranging from 82 upward. The octane number of neohexane recoverable from the alkylate is around 95.

These alkylates are excellent high-octane blending components for the manufacture of 100-octane aviation gasoline.

Aromatization

Certain aromatic compounds have exceptionally good octane numbers and are therefore good aviation gasoline blending components. Until recently the principal source of materials of this type was the destructive distillation of coal. Now, however, the petroleum industry has developed several processes wherein petroleum fractions may be converted catalytically or thermally by aromatization into products containing high percentages of aromatic compounds.

This may be defined as the formation of aromatic compounds from straight-chain compounds through cyclization and dehydrogenation. For example, heptane may be aromatized to toluene as follows:



Heptane Toluene

Similarly, hexene and hexane may form benzene, octenes and octanes may form ethyl benzenes, etc.

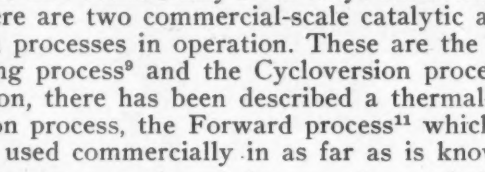
There are two commercial-scale catalytic aromatization processes in operation. These are the Hydroforming process[9] and the Cycloversion process[10]. In addition, there has been described a thermal-aromatization process, the Forward process[11] which is not being used commercially in as far as is known.

There is a scarcity of data on the catalytic processes. The catalysts have not been announced and the operating conditions have not been clearly defined. One is said to operate at around 1000° F[9]. The thermal process operates in the temperature range from 1050° F. to 1075° F. at around 225 pounds per square inch with exceptionally long contact times.

In the Hydroforming process, selected naphthas and hydrogen are charged, selected naphthas in the Cycloversion process, and gas oils in the Forward process. The desired aromatic compounds may be recovered from the products by extraction and fractionation.

Cyclization

Another potential source of high-octane hydrocarbons is the cyclization of aliphatic hydrocarbons to naphthenic compounds. For example, pentene may be cyclicized to cyclopentane



Pentene — 1 Cyclopentane

This has been done in the laboratory but as far as is known no specific commercial processes have been developed for this purpose.

Polymerization

Catalytic polymerization or to be more exact, catalytic selective polymerization, is an important process type in the production of high-octane hydrocarbons. Polymerization may be defined as the reaction between olefinic hydrocarbons to produce other olefinic compounds of higher molecular weight. The olefins thus formed are not suitable for blending directly into aviation gasoline because of their instability and somewhat lower octane numbers than those of the corresponding paraffins. Upon hydro-

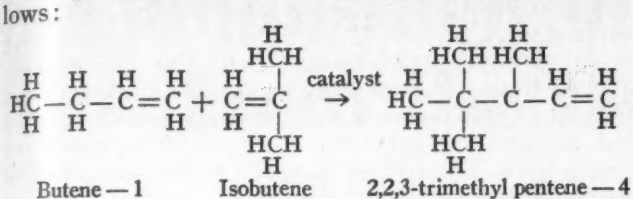
TABLE 4

Comparison of Commercial Alkylation Processes

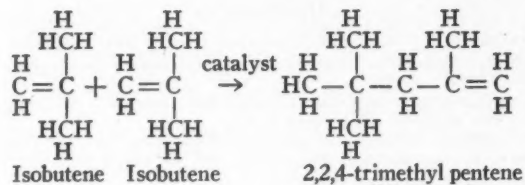
PROCESS	Sulfuric Acid	Hydrofluoric Acid	Neohexane
Charge material	butenes, isobutenes, isobutanes	butenes, isobutenes, isobutanes	ethene, isobutane
Catalyst	H_2SO_4(88-90%)	HF (100%)	none
Temperature, °F	30–50	68–86	920–960
Pressure, lbs/sq. in	low	low	4500
Isoparaffin-olefin ratio	5:1 to 10:1	3:1–	7:1 to 3:1
Catalyst-hydrocarbon ratio	0.7:1 to 2:1	.....	.....

genation however, they become very satisfactory blending agents.

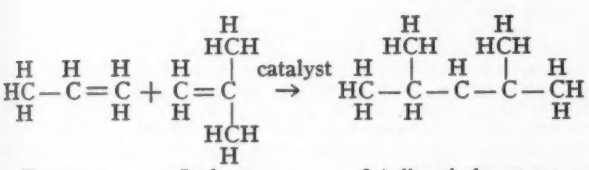
Sample polymerization reactions are shown as follows:



Butene — 1 Isobutene 2,2,3-trimethyl pentene — 4 (Isooctene)



Isobutene Isobutene 2,2,4-trimethyl pentene — 4 (isooctene)



Propene Isobutene 2,4-dimethyl pentene — 5 (isoheptene)

Such reactions as these may be carried out with or without catalysts. However, in the manufacture of high-octane hydrocarbons using selected feed stocks composed of four-carbon-atom olefins, catalysts are employed.

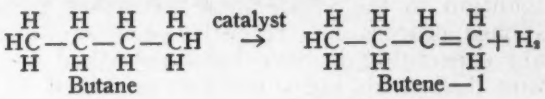
There are several catalytic-polymerization processes which are or are not claimed to be adaptable to selective operation. These are the "Hot" Acid process[12], the Solid Phosphoric Acid process[13,14], and the Copper Pyrophosphate process[15]. In addition there is said to be another process in operation which uses liquid phosphoric acid as a catalyst.

A brief comparison of the polymerization processes is given in Table 5.

These processes produce good yields of polymer gasolines which contain 70 to 90 percent of octenes of 80- to 85-octane number, which when hydrogenated have octane numbers of 90 to 100. The hydrogenated polymers are used in aviation-fuel blends as high-octane blending agents.

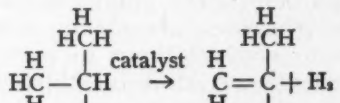
Dehydrogenation

From the foregoing brief discussion, it is shown that olefins are necessary charge materials in both alkylation and polymerization processes. These olefins are available in large quantities from the various thermal- and catalytic-cracking processes but in many instances are not of the right type or proportion. For example, the cracked gas may contain sufficient butenes but insufficient isobutenes for process requirements from the standpoint of yield and quality of product. In order to correct this situation, catalytic dehydrogenation was developed. Dehydrogenation may be defined as the removal of hydrogen from hydrocarbon molecules without rupturing any carbon-to-carbon bonds. Thus butane may be dehydrogenated catalytically to butene:



Butane Butene — 1

Similarly isobutane may be dehydrogenated to isobutene:



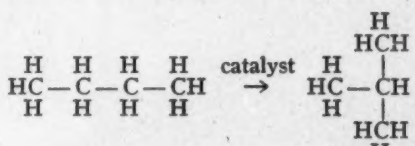
Isobutane Isobutene

Other paraffins may be dehydrogenated to the corresponding olefins.

One commercial dehydrogenation process[16] has been developed and placed in operation at a number of plants. This process converts C_2, C_3, and C_4 paraffins to the corresponding olefins with yields claimed to be 90 to 95 percent of the theoretical. The catalyst is chromium oxide on an alumina base, the operating temperature range 932° F. to 1382° F., and the pressure approximately 15 pounds per square inch. The hydrogen produced is suitable for charging to hydrogenation processes.

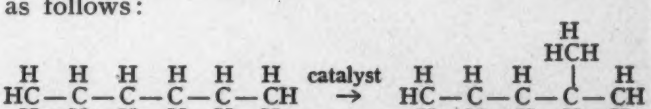
Isomerization

The alkylation processes require relatively large amountsof isobutane for use as charge material and the polymerization processes can produce products of higher quality with a large proportion of isobutene in the feed. These requirements are too great in most cases for the normal supply of isobutane and this necessitatts the use of conversion processing to produce the needed isobutane from the large available supply of butane. This conversion is affected by means of catalytic isomerization which may be defined as the alteration of the structure of a compound without loss of any of its component parts. Butane may be isomerized to isobutane as follows:



Butane Isobutane

Similarly hexane may be isomerized to isohexane as follows:



Hexane Isohexane 2-methyl pentane

Two vapor-phase butane-isomerization processes[17,18] have been developed and have been applied commercially which utilize as a charge material hy-

TABLE 5

Comparison of Commercial Catalytic-Polymerization Processes

PROCESS	Hot Acid	Solid Phosphoric Acid	Copper Pyrophosphate
Charge material	butenes, butanes, isobutenes	butenes, butanes, isobutenes	butenes, butanes, isobutenes
Catalyst	H_2SO_4 (63-72%)	H_3PO_4*	copper pyrophosphate†
Temperature, °F.	167-212	350-500	400-425‡
Pressure, lbs./sq. in.	.....	600	450-900‡
Isoolefin-olefin ratio	0.5:1 to 1:1	0.5:1 to 1:1	....
Catalyst-olefin ratio	1:1 to 2:1	.....	.....

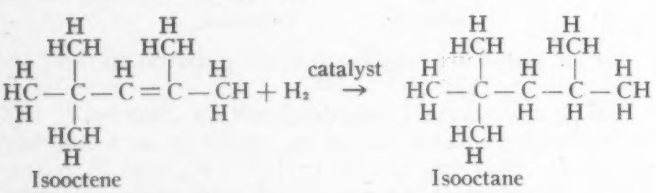
* Catalyst supported on unactive ceramic base. † Catalyst in form of pellets, used in beds. ‡ Non-selective operating conditions.

drocarbon gas composed essentially of butane. The catalysts are composed of halides of such metals as aluminum, zinc, and boron, usually deposited on inactive ceramic bases. In conjunction with the solid catalyst, anhydrous HCl gas is used. The temperatures range from 120° F. to 200° F. in one process, and 300° F. to approximately 400° F. in the other. Pressures range from from 400 to 450 pounds per square inch. The yields claimed are from 40 to 50 percent based on the charge butane in once-through operation.

In addition to the vapor-phase processes, a new liquid-phase process has recently been announced. No data concerning it have been published except the claim that yields are somewhat increased.

Hydrogenation

As was noted before, the polymers formed in the polymerization processes are olefins which require hydrogenation to convert them to paraffins before they can be used as aviation-fuel blending components. Hydrogenation converts olefins to paraffins as illustrated as follows:



There are two low-pressure hydrogenation processes[19,20] and one high-pressure process[21] which are in commercial operation. The low-pressure methods utilize activated nickel as a catalyst and operate at temperatures of 300° F. to 375° F. and pressures of 15 to 75 pounds per square inch. The charge consists of hydrogen and isooctenes. The high-pressure method is said to use a molybdenum sulfide catalyst and operates at a pressure of around 3000 pounds per square inch. The charge material is the same as that for the other methods.

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Loading aviation gasoline at one of the plants of Standard Oil Company of New Jersey.

Composition of Paraffin Waxes From the Fischer-Tropsch Water-Gas Synthesis

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(Translated from "Brennstoff-Chemie," Vol. 16, P. 141-148, 1935)

IN PREVIOUS contributions concerning the manufacture of gasoline by the water-gas reaction we had already referred to the formation of very high melting-point paraffin wax hydrocarbons[1]. As we have since then obtained workable quantities of hard waxes in the pilot plant of the institute, we have carried out a rather intensive analysis of these waxes at the instance of Dr. Franz Fischer.

About 5-10 percent of the paraffins which are formed in the water-gas reaction process to make gasoline possess a melting point above room temperature. Part of these so-called hard paraffin waxes is in solution in very high-boiling synthetic oils which are also produced, and this hard waxy portion can be easily separated in a chilling operation. Paraffin obtained in this manner shows a melting point of about 50° C. and consists of the paraffin hydrocarbons from about C_{17} H_{36} to C_{25} H_{52}. The much higher melting point paraffin concentrates itself in increasing quantities in the catalyst itself.

Investigations by Fischer and Koch[2] have shown that a contact catalyst will become saturated with paraffin equal to about one and one half times its own weight, especially during long reaction periods. This occurs without any appreciable loss in catalyst activity. The paraffin wax isolated from the catalyst by extraction with light naphtha or benzol shows a melting point of 70-80° C. A part of this hard paraffin is insoluble in ether, and the latter shows a melting point of 92° C.

A similar product has been made in earlier work by Fischer and Koch[3] by the catalytic reduction of carbon monoxide at 15 atmospheres of pressure. From this synthetic material there was fractionated by means of crystallizing from xylol an intermediate portion melting between 104° and 117°. The molecular weight of this fraction was approximately 1000. As these rather crude separations into low- and high-melting-point portions were carried out in a preliminary manner we undertook a more complete separation of these types of hard waxes. Also, it was of prime interest to determine the paraffins of highest molecular weight which are synthesized from carbon monoxide, and to determine the melting point of these very high-boiling constituents.

It could be seen from the start of our work that a separation by means of chemical reagents was not at all feasible, since the possibility is very slight that one can obtain definite and characteristic derivatives in the homologous series of the paraffin hydrocarbons. The results were also without significance in attempts made to separate branch-chain hydrocarbons from the normal liquid members among the paraffins by treating with such chemical reagents as antimony pentachloride, chloro-sulphonic acid, and the like. In view of the failure of such chemical methods to obtain accurate separations we have therefore chosen in the work described below only those methods of separation in which definite physical properties could be accurately determined.

Physical Methods Used in the Separation of Individual High Molecular Weight Paraffin Hydrocarbons

1. Separation Based on Differential Solubility.

Solubility of homologous members in the paraffin series is one property very much dependent upon the molecular weight of the hydrocarbon. The solubility of a paraffinic material at a definite temperature in a definite amount of solvent decreases rapidly with an increase in the molecular weight of the hydrocarbon. Based on the variable solubility one may proceed to employ three different methods of separation.

A. Extraction.

In this procedure one should be a solvent which will dissolve only the lower-molecular-weight portions, while the higher-weight materials are only slightly soluble in even a large excess of the solvent. To determine suitable solvents which are supposed to be inert to paraffin we chose and examined about 28 organic liquids and classified them as shown in Table 1.

TABLE 1

Solubility of Synthetic Hard Wax in Organic Solvents. Paraffin (M.P. 80° C.), added to a large excess of the following liquids at their B.P. is:

Completely Soluble In:	Partly Soluble In:
Amyl Alcohol	Propyl Alcohol
Benzyle Alcohol	Butyl Alcohol
Cyclohexanol	Ether
Ethyl Acetate	Chloroform
Butyl Acetate	Dichlor-ethylene
Amyl Acetate	Dioxan
Benzine	
Benzole	**Insoluble In:**
Cyclohexane	
Toluol	Acetic Acid
Xylol	Methanol
Tetralin	Ethanol
Chloro-benzole	Acetone
Bromo-benzole	Methyl-ethyl Ketone
Nitrobenzole	
Carbon Tetrachloride	
Tetrachloroethylene	

The five solvents which only partially dissolve hard paraffins are rather questionable for employment in any precise methods of separation.

B. Fractional Crystallization.

If one completely dissolves hard paraffin in a solvent at an elevated temperature it will be found that the highest-molecular-weight material or hardest waxes will crystallize out first upon slowly cooling the solution. Any method of separation would have to provide a removal of the insoluble wax at the specific temperature before cooling further. Trials in this direction present many difficulties—one is compelled to filter at an elevated temperature which must be maintained very constant. Filtration at elevated temperatures causes evaporation of the solvent which is unavoidable, and this causes a further precipitation of waxes otherwise held in solution; the filter likewise becomes clogged with very fine crystals which are just about to precipitate out.

C. Fractional Precipitation.

A third method of separation consists of using a mixture of various solvents. If one adds to a solution of the wax in a good wax solvent a liquid in which paraffin itself is insoluble, but which is miscible with a solvent in all proportions, then the wax (soluble in the binary mixture) will decrease (at constant temperature) in proportion to the added liquid or so-called "precipitating liquid." If various soluble constituents are present in the solution then the most difficultly soluble (highest mol. wt.) paraffin hydrocarbons will precipitate out first. Such a precipitation can be made practical only if it can be carried out at room temperature, since otherwise the above-mentioned difficulties of high-temperature filtration would again be encountered. However, it was not possible to find a solvent which would hold any appreciable amount of paraffin in solution at, say 20° C.

2. Separations Based on the Difference in Vapor Pressures.

The most numerous methods for separating various members of an homologue depends on differences in their vapor pressures, and therefore on a definite difference between boiling points. Most of the work in paraffin separations has been done by this method—namely, by means of distillation.

One can mention here the work of Kraft[4] on lignite paraffin; also the work of Fischer and Glund[5] on waxes present in crude coal tar. Buchler and Graves[6], Francis[7], Myers and Stegemann[8], and Ferris, Cowles, and Henderson[9] have employed this method of separating waxes from petroleum. Distillations are conducted at low pressures, such as from 15 mm. to as low as 0.05 mm. Among other things the concensus of opinion is that in working with paraffin wax appreciable cracking will take place with these hydrocarbons when they are heated in any type of apparatus above 300° C. The pioneers in this field mentioned above were therefore not able to distill waxes of over 35 carbon atoms per molecule.

A new tool for separating high-boiling-point materials by distillation is the so-called "molecular" distillation method first used by Bronstedt and V. Hevesy[10] in separating the isotopes of mercury. The apparatus consists of a means to vaporize and immediately condense at extremely low pressures and at temperatures far below the boiling point. The method has already been used in the case of waxes by Washburn[11] who developed three types of flasks and named by him "molecular stills."

Gilchrist and Karlik[12] perfected a micro apparatus for distillation and separated mixtures of $C_{20}H_{42}$ and $C_{24}H_{50}$ with $C_{30}H_{62}$. By choosing the proper temperatures this method proved highly successful.

Carothers[13] employed the molecular still of Washburn and separated high-molecular-weight hydrocarbons. By extraction and crystallization crude material could be separated into the C_{20}, C_{30} and C_{40} hydrocarbons. Another portion melting between 102° C and 112° C. was distilled at a pressure of below 10-5 mm. mercury, obtaining normal paraffins of C_{50}, C_{60} and C_{70}. At 300° C. evidences of cracking appeared so that the 110°-114° C.-melting point residue could not be investigated further. The molecular weight of this material showed about 1300; the authors concluded that the material was a mixture of C_{80}, C_{90} and probably C_{100} paraffin hydrocarbons.

This review of the possible physical methods for separating hydrocarbons has shown that there are two possibilities as to procedure, namely:

1. Extraction with various solvents, and
2. Distillation at pressures below 10-5 mm. of mercury.

Our investigation of the hard waxes proceeded therefore along the following lines, namely, to extract first the crude material and remove all low-melting-point material below 80° C. The insoluble material remaining was then fractionated more closely by means of distillation. However, to isolate material melting over 100° C., the most interesting series of waxes for separation, the residue was again subjected to extraction as such melting point material could not be further distilled due to cracking; splitting reactions are in agreement with the observations of Carothers and co-workers.

Separation by Extraction

The paraffin used for our separations was extracted from the catalyst for several weeks with benzene. It originally was derived from the pilot plant of the institute. The raw wax used in extraction was found in the nickel-manganese-aluminum catalyst used in the water-gas reaction. The extraction was carried out altogether in three successive stages and yielded, as shown below, the paraffins Nos. 1, 2, and 3. Since the extracted paraffin was quite dark in color it was first bleached with an active bleaching-clay at 100° C. The purified paraffin was a straw-colored odorless product with properties shown in Table 2.

TABLE 2
Melting Point and Molecular Weight of Crude Paraffin Wax in Tests I, II and III.

TEST	M. P. (°C.)	Aver. Mol. Wt.
I	70	570
II	80	630
III	95	740

Molecular weights were determined by the boiling-point method of Rieche.

1. Extraction of the Crude Paraffin with Ether.

The first separation was made by extraction with ether as follows:

100 grams of wax were extracted with 750 cc. of ether in an extraction apparatus designed by Peters[14]. The extract was then evaporated to a small volume and the paraffin in solution precipitated with an excess of alcohol. The snow-white crystals were sepa-

rated on a suction-filter, well washed free of solvent, and dried in a drying chest.

The results of the extraction are given in Table 3.

TABLE 3
Extraction of Hard Paraffin with Ether.

Test No.	Time (Hrs.)	ETHER INSOLUBLE			ETHER SOLUBLE		
		Percent	M. P.	Mol.Wt.	Percent	M. P.	Mol.Wt.
I.....	48	23	88 °C.	700	77	40 °C.	490
II.....	48	22	98 °C.	860	78	60 °C.	610
III.....	22	40	106 °C.	...	60	60° C.	...

The melting-points were determined in a melting-point apparatus described below. These melting-points are still somewhat wide-ranged. The determination of the molecular weight of hard paraffin waxes presented several difficulties. Since the rise in boiling-point for equal amounts of wax always decreases with increase in molecular weight, one can only employ accurately constructed apparatus.

To begin with any super-heating of the solvent must be carefully avoided. Determinations made in the beginning using the Beckman apparatus, and later the micro apparatus of Pregel[15] gave unreliable results. The semi-micro apparatus of Rieche[16] gave good agreement in the values obtained. Nevertheless, an experimental error of 5-8 percent must at least be allowed in determining molecular weights of material of over 1000. One can therefore not determine with two or three determinations very definitely whether a paraffin wax will contain 65 or 75 C-atoms per molecule. As a carbon-hydrogen analysis of long-chain paraffins results in figures which are not far separated, there remain only the melting point and molecular weight as constants that can be used in order to obtain some picture of the average constitution of these higher waxes. We therefore employed the Rieche method for molecular-weight determination.

The melting-point of the residues points to the presence of normal paraffins of similar molecular weight:

	Mol. Wt.	M. P. (°C.)
Res. from Test I.....	700	88
n-C_{50} H_{102}.....	702	92
Res. from Test II.....	860	98
n-C_{60} H_{122}.....	842	98-99

The ether-soluble paraffin shows a melting point far below that called for by its molecular weight:

	Mol. Wt.	M. P. (°C.)
Sol. paraffin Test I.....	490	40
n-C_{35} H_{72}.....	492	75
Sol. paraffin Test II.....	610	60
n-C_{45} H_{92}.....	632	85

One is led to suspect that the ether-soluble paraffin fractions consist mainly of low-melting iso-paraffins. It is also possible that the low melting point is due to small amounts of oil still adhering to the wax.

2. Extraction with Dichlor-ethylene.

In order to fractionate the ether-insoluble material further, dichlor-ethylene was used to extract a portion of the insoluble wax. This time 250 cc. of solvent were used for every 10 grams of paraffin wax in a smaller type of extraction vessel. The procedure following the extraction is the same as previously described. The results are shown in Table 4.

TABLE 4
Extraction of the Ether in-soluble Hard Wax with Dichlor-Ethylene.

Ether Insoluble Residue from Test	Extraction Time (Hrs.)	CHCl—CHCl Insoluble			CHCl—CHCl Soluble		
		Percent	M. P.	Mol. Weight	Percent	M. P.	Mol. Weight
I.....	24	0	...	....	100	88 °C.	700
II.....	45	20	107 °C.	1140	80	90 °C.	835
III.....	24	50	108 °C.	1180	50	90 °C.	....

The ether-insoluble residue from Test No. 1 was completely soluble in the chloro solvent. Paraffins melting over 100° C. are apparently not present in this fraction while the paraffins in Tests No. 2 and No. 3 (20-50 percent of melting-point material of about 108) remained undissolved.

3. Extraction with Chloroform.

In order further to separate the residue which was insoluble in the above solvent, chloroform was next used in a further extraction. The paraffin formed a gelatinous mass with the chloroform and the solvent channeled through the mass upon filtration. In order to avoid this difficulty 10 grams of the paraffin wax to be extracted were spread upon a small porous plate and the latter heated to 110° for half an hour. The plate absorbed the melted paraffin very rapidly and upon cooling it was broken into small pieces. The latter were placed in an extraction vessel, and this procedure presented no difficulty. The extraction proceeded smoothly and results are shown in Table 5, of this extraction of residues insoluble in dichlor-ethylene (from Test No. 2 above).

TABLE 5
Fractional Extraction with Chloroform of Test No. 2 Residue Insoluble in Dichlor-Ethylene.

FRACTION	Ext'n Time	$CHCl_3$ SOLUBLE		M. P. °C.
		Gms.	Percent	
1.....	1	0.685	6.9	100 –103
2.....	2	0.365	3.7	101 –103
3.....	6	0.585	5.9	102 –103.5
4.....	18	0.587	5.9	103.5–105
5.....	29	0.795	8.0	104.5–106
6.....	66	1.358	13.5	106 –107
7.....	87	1.253	12.5	107 –108.5

Approximately 56.5 percent of the material went into the solution after extracting 209 hours. The paraffin remaining within the porous plate was recovered by extraction with benzol for 24 hours. Three and one half grams were recovered (35.3 percent) and this material showed a melting point of 112-113° C. In similar manner 10 grams of Test No. 2 insoluble residue and 10 grams of Test No. 3 residue were worked up. The results are shown in Table 6.

TABLE 6
Extraction with Chloroform of Tests No. 2 and No. 3 Residues Insoluble in Dichlor-Ethylene.

CHCl—CHCl Insoluble from Test No.	Ext'n Time (Hrs.)	$CHCl_3$—Insoluble			$CHCl_3$—Soluble		
		Percent	M. P. (°C.)	Mol. Wt.	Percent	M. P. (°C.)	Mol. Wt.
II.....	214	31	112–113	1330	65	105–107	980
III.....	196	58	113–114	1640	36	104–106	...

The extraction residues contain approximately 100-120 carbon atoms per molecule based on the molecular weight. In one example the ultimate analysis of the extracted paraffin was carefully scrutinized in order to prove whether the extracted materials had been attacked or had become contaminated (separation of polymerized dichlor-ethylene). An ultimate analysis of the chloroform-insoluble residue from Test No. 3 (M.W. = 1640) showed as follows:

85.37 percent C, 14.5 percent H; cal. for C_{115} H_{232} (m. wt. = 1614): 85.51 percent C, 14.49 H.

0.1304 gm. substance gave 0.4082 CO_2, and 0.1690 gm. H_2O by the analysis.

The paraffin was therefore not contaminated.

We next proceeded to attempt to separate synthetic paraffins of still higher molecular weight present in our mixtures. The chloroform extraction was then repeated on the residues which were found to have been insoluble in the above procedures; the results are shown in Table 7.

TABLE 7
Continuation of Chloroform Extraction.

Previous $CHCl_3$ Insoluble Residue from Test	Ext'n Time (Hrs.)	$CHCl_3$—Insoluble			$CHCl_3$—Soluble		
		Per-cent	M. P. (°C.)	Mol. Wt.	Per-cent	M. P. (°C.)	Mol. Wt.
II	187	63	113-114.5	1750	36	110-111	1200
III	187	75	115.5 116.5	2140	21	109-110.5	....

It was possible by chloroform extraction for several days to bring into solution some 20-35 percent of very high-molecular-weight paraffin. While the melting point of these residues were not appreciably higher than those from the first chloroform extraction their molecular weight was appreciably increased. The residue from Test No. 3 (m. w. over 2000) appears to be composed of paraffin molecules of approximately 150 carbon atoms.

4. Recapitulation of Extraction Results.

The experiments have shown that complex paraffin mixtures can be separated with reliable results by extracting with various solvents. Even though no definite hydrocarbon could be isolated, one nevertheless is able to effect a division of the material into groups of similar molecular weight, and therefore similar physical properties. It is not possible, however, definitely to determine the number of hydrocarbons present in such groups. A paraffin separated by extraction can well be composed of only very few normal paraffin hydrocarbons, as well as composed of a wide mixture of normal or iso-paraffins.

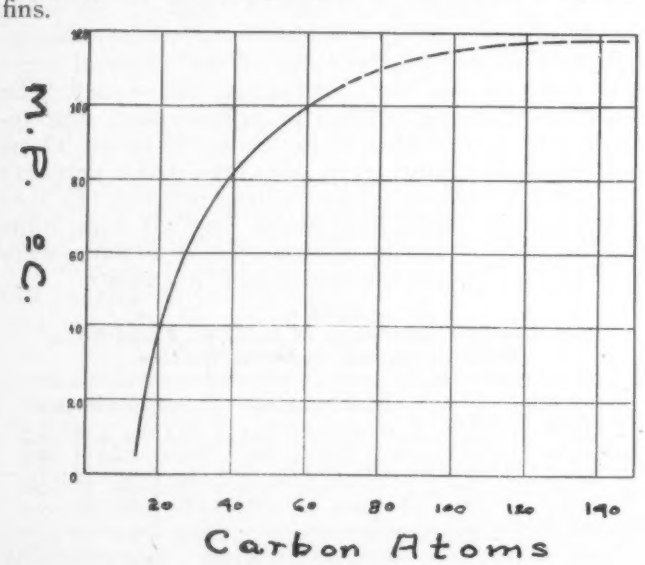

FIGURE 1
Relationship between M. P. and number of C-atoms in the N-paraffin hydrocarbons

A closer picture of the composition of such a mixture can be obtained only by a very careful fractional distillation. The determination of the melting point and molecular weight is nevertheless always the most valuable criterion in determining the average composition of synthetic paraffins apparently composed of many hydrocarbons. In Table 8 there are shown the melting points for high-molecular-weight normal paraffin as found in the literature classified by various investigators.

TABLE 8
Melting Points of High-Molecular-Weight Normal Paraffins from Literature.

N—Paraffin	Melting Points (°C.) According to Various Authors						
	I	II	III	IV	V	VI	VII
$C_{30}H_{62}$	65.6	....	66.1	66	65.5	65-66	65.5
$C_{31}H_{64}$	68.4	68.1	....	68	....	....	....
$C_{32}H_{66}$	69.8	70.0	....	70	....	....	74-75
$C_{33}H_{68}$	71.8	....	....	72	....	....	....
$C_{34}H_{70}$	73.0	....	72.9	73.5	....	....	....
$C_{35}H_{72}$	74.0	74.7	....	75.	....	....	....
$C_{36}H_{74}$	76.0	....	....	76	....	....	78.5
		IX					
$C_{38}H_{78}$	....	79.4	....	....	....	....	....
$C_{40}H_{82}$	....	....	....	....	....	80.5-81	....
$C_{50}H_{102}$	....	....	....	....	....	91.9-92.3	....
$C_{54}H_{110}$	....	....	....	....	95	....	....
$C_{60}H_{122}$	....	....	....	....	....	98.5-99.3	....
			VIII				
$C_{62}H_{126}$	....	....	101-102	....	100.5	....	....
$C_{64}H_{130}$	....	....	....	....	102.0	....	....
$C_{70}H_{142}$	....	....	....	....	....	105-105.5	....

OBSERVERS—Kraft [4]; Kraft [17]; Petersen [18]; Hildebrand and Wachter [19]; Gascar [20]; Carothers [13]; Levene, West, Van der Scheer [21]; Heil and Haegel [22]; Morozewic [23].

If the values of the melting point of the normal paraffins are graphed as ordinates with the number of carbon atoms as abscissa it will be found that the points will lie on a curve similar to that obtained by Levine and coworkers (see Figure 1).

Upon closer investigation of this curve it is seen that it is of exponential type approaching a limit asymptotically. Extrapolated graphically the limit appears to be about 118° C. Accordingly it would appear that there could be no normal paraffin of melting point over 118 no matter how large the molecule could become, the iso-paraffins being excluded since they are always of a lower melting point. While an increase of one CH_2 group in the chain in the lower homologous series greatly increases the melting point, such increase becomes smaller with length of chain so that finally molecules of over 100 carbon atoms will show only an exceedingly small value. In this respect the melting-point curve shows a relationship similar to that of the carbon-hydrogen ratio of paraffin hydrocarbons, namely, the paraffins approach the formula $C_n H_{2n}$ asymptotically.

The experimental results are in good agreement with the mathematical facts stated above. While the melting point increases rapidly with the increase in molecular weight in the case of the first two fractions, it is seen that the melting point increases are no longer evident in the case of the second chloroform extraction despite a large increase in molecular weight. Even a wax with a molecular weight of over 2000 showed a melting point no higher than 116.5.

The products obtained by chloroform extraction represent the very highest members of the paraffin hydrocarbons which have been isolated up to date. They are composed of chains of from 100-150 carbon atoms. As far as their molecular weight is concerned they would be classified as hemi-colloids. One obtains these high-molecular-weight paraffins as white odorless crystalline powders, absolutely devoid of any adhesive properties, by precipitating them from their boiling benzol solutions with alcohol. The solidified material is exceedingly hard and brittle and cannot be scratched with the fingernail. Specific gravity of this high-melting-point paraffin is quite high. Specific gravity of the ether-insoluble residue in Tests No. 1 and 2 showed 0.938-0.944 at 20° C. The residue insoluble in dichlor-ethylene (mp. 108) in Test No. 3 showed a gravity of 0.959, melting at 116.5; the paraffin-insoluble chloroform showed a gravity of

0.965. It seems therefore that the specific gravity also approaches a limiting value with increase in molecular weight.

It is also interesting to note that these high-molecular-weight paraffins show a very high Dielectric constant. By merely gentle rubbing in a mortor or weakly pressing the powdered material it becomes strongly electrically charged; this charge is not completely removed when the material is exposed several hours to ultra violet light.

Separation by Distillation

After the synthetic hard wax had been separated into various fractions by extraction, attempts were next made to narrow the separation further by means of distillation. By this means it would be shown whether these types of waxes were composed of only relatively few hydrocarbons, as was the case in paraffin mixtures prepared by Carothers[46]; or whether the number of paraffin hydrocarbons is exceedingly large in materials of this type. Only in the first case could we possibly hope to be able to isolate individual hydrocarbons. It can also be assumed that by continued fractionation the strongly branched iso-paraffins would reveal their presence. The presence of naphthenes or condensed aromatic hydrocarbons are excluded to begin with as they are already absent from our synthetic product, as was shown by composition of the lower-boiling fractions from synthesis material.

1. Distillation Apparatus.

As mentioned above, the distillation was carried out in a so-called "molecular still," such as was used by Carothers and his coworkers. A 500-cc. flash with a 31 cm. long and 6 cm. wide neck was used as a distillation vessel. Sealed into and extending from the top of this flask there is inserted a water-cooled condenser which extends to about 5 centimeters above the flask. (See Figure 2.)

As shown in the diagram (Figure 3), the portion of the flask above the side exit tube contains a circular water condenser blown into the neck of the flask itself. An aluminum block heated with resistance wire served as a means for heating the flask at uniform temperatures.

The bulb of the flask is fitted snugly into a spherical depression in the metallic block. A temperature regulator[24] was used in the electrical heating system. As shown in the diagram, flask F attached to the side arm serves as a receiver to condense any cracked products which might form. Large fluctuations in the pressure were measured by barometer M and very small changes by the Macleod manometers ML. To secure a vacuum of below 10-5 mm. a mercury pump P is next inserted in the apparatus. An oil pump is installed ahead of the mercury pump to reach ordinary low pressures. Receiver A is cooled with liquid air. Attached upright from the suction to the oil pump is a three-litre gas flask which serves as a pressure equalizer and for vacuum storage.

In carrying out a distillation the material is charged into the flask, which is then brought to a pressure of 1 mm. by means of the oil pump. The mercury pump is then connected into the system and a vacuum brought to below 10-4 mm. In order to remove the last traces of gases the cooler A was used to maintain the vacuum; the cooler is kept at a very low temperature with liquid air. A pressure of below 10-5 mm. was reached within one hour. In order to maintain this vacuum for several days one can employ the three-litre flask as a pre-vacuum for the mercury pump. After a distillation had been completed the metallic heating block was disconnected and after the apparatus had cooled to room temperature air was gradually allowed to enter the flask. The paraffin which sublimed on the inserted cooler was next removed and scraped onto a watch glass and weighed.

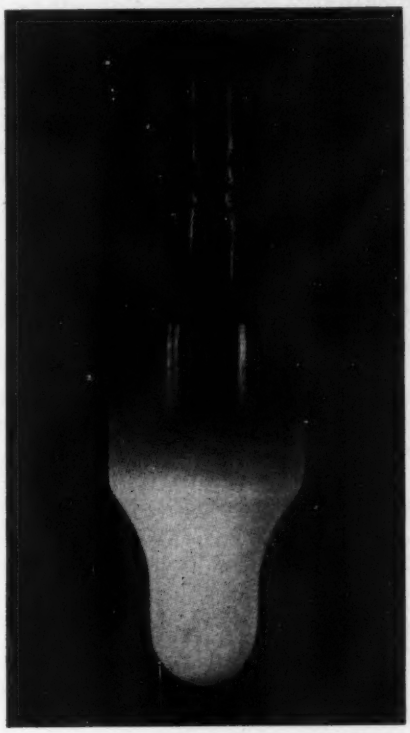

FIGURE 2
Cooler with condensed paraffin.

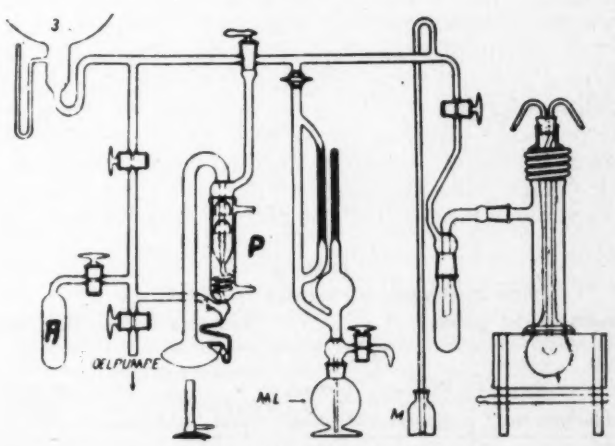

FIGURE 3
Diagram of arrangement for high vacuum distillation.

In order to determine the melting points of these fractions accurately an apparatus was constructed[25] as shown in Figure 4. A stream of carbon dioxide gas is used to agitate a bath of paraffin oil employed as a heating medium for the test tube containing a thermometer with melting tubes attached. The leg of the melting point apparatus is electrically heated. This is accomplished by chromium nickel resistance wire about 1 meter long, wound on asbestos around the glass. Heating is controlled with a rheostat and is

so regulated that the temperature rise is held within 0.1° C. per minute at about the melting point of the material. The thermometer with the melting point tube attached (dia. 1 mm.) is inserted in a test tube which serves as an air bath. The thermometer is

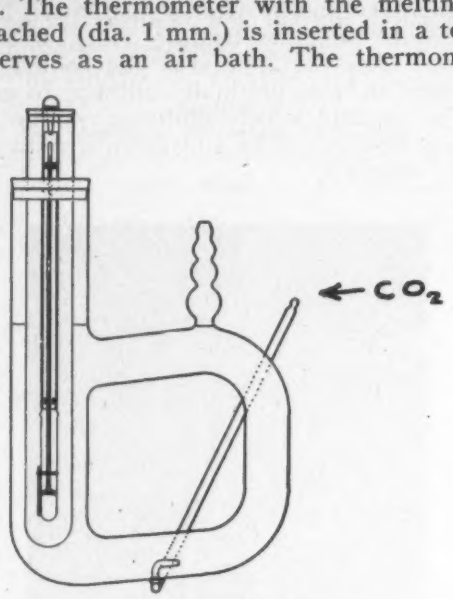

FIGURE 4
Melting point apparatus.

graduated in 0.1° C. and calibrated so that no correction is necessary. In order to observe the actual melting point, the apparatus is illuminated from the side and a reading glass is used for viewing the melting-point tube itself.

2. Distillation Experiments.

Ten grams of waxy residue insoluble in ether (from Test No. 2) were used as material to be distilled in the special apparatus. Its melting point is 98° C., M.W. 860. The material was spread upon 10 grams of pure and previously heated pumice stone in order to afford a large surface of the wax to be distilled. The results of the first distillation, which occupied several months, is given in Table 9 below.

The distillation was stopped after the eighteenth fraction due to strong cracking. This became visible as shown by an increase in the pressure. At this point the pressure was five times 10-5 mm.; the distillate was also colored. Fraction 12, for instance, showed a pale yellow color compared to the first fraction which was snow white crystals. Colors increased with the succeeding cuts. For instance, the crystals in cut No. 18 were deeply yellow and also pasty. Cracking was also evident as judged by the burnt odor of the residue after cut No. 18. A lowering of the melting point of the last fraction again showed that cracking had occurred.

Our observation that paraffin begins to crack at approximately 290° (aluminum block measurements) is in good agreement with other workers in this field. High-molecular-weight paraffins are not stable above this temperature. As products of this cracking reaction one also obtains traces of gases, highly colored yellow pasty products, and a poorer vacuum. It can therefore be seen that with this exact type of distillation procedure practically no more than 65 percent of a synthetic wax of 98° C. m.p. can be accurately distilled. The high-molecular-weight fractions remaining as residue cannot be separated further by succeeding distillations.

Up to 65 percent fractionation the distillation itself proceeded very evenly. It appears that a great number of hydrocarbons are present in about equal proportions since it can be seen that there is no great increase of material in any definite temperature range. The individual fractions were distilled a second time in order to continue seeking definite hydrocarbons present in these cuts. Successive fractions which show about the same melting point were first combined. The material was distilled without using any carrier such as pumice. The results of the second separation made by distillation as shown in Table 10.

TABLE 9
First Distillation of Residue from Test No. 2.
Quantity—10 grams. Pressure below 10-5 mm.

Fraction No.	Dist'n Time (Hours)	Temp. °C. in Al-Block	DISTILLATE IN		Melting Point °C.
			Percent Total	Gms. per 100 Hours	
1	96	200	18.2	1.9	80. – 83.5
2	72	200	4.1	0.57	85. – 87.3
3	186	200	4.5	0.24	88. – 89.5
4	158	200	2.1	0.13	90. – 90.5
5	113	200	1.0	0.10	90. – 91.5
6	138	200	1.1	0.08	91. – 91.7
7	90	200	0.5	0.06	91. – 91.7
8	70	210	0.8	0.11	92. – 92.5
9	50	210	0.5	0.09	92. – 92.5
10	143	220	3.0	0.20	92.5– 93.7
11	117	235	3.8	0.33	94.5– 95.5
12	92	245	4.3	0.47	95.5– 96.6
13	66	250	3.0	0.45	96.5– 97.7
14	88	270	4.5	0.51	98. – 98.7
15	70	280	3.9	0.55	99. –100.2
16	97	280	3.0	0.31	100. –101
17	93	290	3.6	0.39	100.5–101.4
18	129	290	3.1	0.11	100. –101.2

TABLE 10
Second Distillation of Residue from Test No. 2
Ether Insoluble Material.
Pressure below 10-5 mm.

Distillation No.	Original Material (M. P.)	Single Fractions	Distillation Time (Hrs.)	Distillation Temp. (°C.)	Percent Distillate	Melting Point (°C.)
I	1 (80-83.5)	a	3	150	7.6	75.5– 76.4
		b	7	150	11.5	78.4– 78 9
		c	9	150	11.6	80.0– 80.7
		d	12	150	10.4	81.3– 81.8
		e	24	150	11.7	82.7– 82.9
		f	3	175	10.0	84.5– 85.1
		g	5	175	11.1	85.5– 86.4
		h	9	175	9.2	87.0– 87.5
		i	2.5	200	10.6	80.0– 89.2
		j	....	200	6.3	91.2– 92.0
II	2 (85.5-87.3)	a	4.0	150	5.4	81.5– 82.3
		b	3.5	175	29.7	84.5– 84.9
		c	7.0	175	26.4	86.0– 86.7
		d	2.0	200	24.5	88.3– 89.0
		e	....	200	14.0	92.0– 92.6
III	3 (88-89.5)	a	25.0	150	10.3	84 – 84.6
		b	4.5	175	15.2	85.5– 86.7
		c	2.5	200	13.7	88.5– 89.
		d	2.0	200	22.0	89.7– 90.
		e	16.0	200	38.8	92.8– 93.2
IV	4, 5, 6, 7, 8, 9 (90-92.5)	a	50.0	150	5	86 – 86.8
		b	15.5	175	16	88 – 88.9
		c	2.5	200	18	89.5– 90.2
		d	6.5	200	26.7	91 – 91.8
		e	15.0	200	22.9	93.0– 93.6
		f	....	210	11.4	95.5– 96.3
V	10, 11 (92.5-95.5)	a	25	175	6.6	89.7– 90.7
		b	45	200	1.5	91.0– 91.7
		c	2.5	210	23.1	92.0– 92.7
		d	5.0	210	16.0	93.5– 94.0
		e	15.0	210	28.4	94.3– 95.3
		f	6.5	210	6.4	95.5– 96.4
		g	....	220	18.0	97.0– 97.9
VI	12, 13, 14 (95.5-98.7)	a α	....	....	8.9	89.5– 91.5
		a β	....	....	9.8	93.5– 94.5
		a α+β	15	210	18.7	.....
		b	7.5	220	11.3	95. – 96.2
		c	20.5	225	26.7	96.5– 97.6
		d	10.0	230	19.0	98.5– 99.2
		e	21.0	235	13.6	100. –100.6
		f	21.0	240	7.5	101.5–102.1
		g	....	250	3.2	103.0–103.8
VII	15,16,17,18	a	18	200	....	Pasty

This second distillation has shown that the fractions from the first separation were far from being anything like individual hydrocarbons. They consist of hydrocarbon mixtures whose melting points are about 10 degrees apart. Greater concentration in any one fraction or larger intervals in the melting points could not be obtained or observed in successive distillations.

A re-distillation of cut No. 6 shows that cracked products remaining from the first distillation can be well removed in later runs. For instance, fraction (A) appears to consist of two layers which could be easily separated from each other. The outer layer (B) consisted of white loose crystals. Under this layer there was a layer of yellow crystals adhering to the condenser (a) which had a lower melting point than fraction B. Fractions following this were all substantially white in color, an indication that low-molecular-weight cracked products were the first hydrocarbons which distilled and condensed on the cooler. In distillation cut No. 7 a fraction was also obtained which was brown in color, of pasty, consistency, part oily and of a burnt odor.

To test the purity of the fractions obtained in the second distillation several of these were subjected to a third distillation. These results are shown in Table 11.

TABLE 11

Third Distillation of the Ether-Insoluble Residue from Test No. 2. Pressure 10-5 mm.

Test No.	Original Material (M. P.)	Individual Fraction (No.)	Distillation Time (Hrs.)	Distillation Temp. (°C.)	Distillate Percent	Melting Point
A	1, a (75.5-76.4)	1	14	100	12.0	60 - 63.3
		2	18	110	21.4	71 - 73.2
		3	6.5	120	15.1	73 - 76.0
		4	20.0	120	31.2	73 - 77.6
		5	5.0	130	10.4	78 - 79.7
		6	....	130	9.9	80 - 83.1
B	IV, d (91-91.8)	1	18	150	1.4	89 - 90.1
		2	21	160	9.9	89.5- 90.4
		3	21	170	23.4	90 - 90.8
		4	21	175	26.6	90.5- 91.5
		5	18	180	21.6	91.5- 92.5
		6	....	190	17.1	93 - 94.5
C	VI. d (98.5-99.2)	1	18	200	5.1	97 - 97.5
		2	18	210	20.3	97.5- 98.1
		3	20	215	26.5	98 - 98.7
		4	26.0	220	33.3	98.8- 99.6
		5	....	225	14.8	100 -100.8

This distillation showed that the material obtained in the various fractions was not at all homogeneous. This is especially true for fraction 1-a in which there is still present a low melting point mixture of hydrocarbons. However, as in the case of the other fractions, only about 50 percent of the distillates showed the melting point of the original fraction. A fourth distillation shown in Table 12 indicates that even this material is still not homogeneous.

TABLE 12

Fourth Distillation of Ether Insoluble Residue from Test No. 2. Pressure 10-5 mm.

Original Material (M. P.)	No. of Cut	Distillation Time (Hours)	Distillation Temp. (°C.)	Distillate Percent	Melting-Point (°C.)
B_4 (90.5-91.5)	1	17	170	50	90.2-90.6
	2	.....	175	50	91.5-92.1
C_3 (98.0-98.7)	1	18	210	50	97.5-98.1
	2	.....	215	50	98.0-98.8

3. Results of Distillation Experiments.

Even though it was not possible by high vacuum successive distillations to obtain individual hydrocarbon from hard paraffin wax, nevertheless some conclusions can be drawn concerning the composition of these synthetic paraffins. The results of our separations by means of distillation can be summarized as follows:

1. High molecular weight paraffins in synthetic wax consist of exclusively hydrocarbon material. They follow the rule that the melting point increases with molecular weight. In the presence of hydrocarbons of other series (naphthenes, olefines, condensed aromatics) a rapid decrease or a sudden increase of the melting point would have revealed their presence.

2. The hydrocarbons present in this type of parifin wax are those of the normal paraffins or only slightly branched iso-paraffins. This can be seen by inspection of Table 13 showing the agreement of the molecular weight of fractions with those of the normal paraffins of similar melting point.

TABLE 13

Molecular Weight of Several Fractions in Comparison With Those of the Normal Paraffins of Similar Melting Point.

Fraction No.	M. P. (°C.)	Mol. Wt. (Det'd)	N—Paraffin	M. P. (°C.)	Mol. Wt. (Cal'd)
I-d	81.3–81.8	561	$C_{40}H_{82}$	80.5–81	563
V-f	95.5–96.4	766	$C_{54}H_{110}$	95	759
VI-f	101.5–102.1	895	$C_{64}H_{130}$	102	899
B-s	91.5–92.5	687	$C_{50}H_{102}$	91.9–92.3	703

One cannot determine definitely, however, whether our fractions consist of normal paraffins or also the iso-paraffins, due to the relatively large errors inherent in any method of determining the molecular weights.

3. The number of higher molecular weight paraffins present in high-melting synthetic wax is very large. Perhaps all the normal paraffins from C-20 to about C-150 together with probably a corresponding number of iso-paraffins are all present in hard wax of synthetic origin. Were only a comparatively small number of hydrocarbons present practically pure individuals would have been obtained in the second distillation as had been shown previously by Carothers. That a very large number of hydrocarbons are equally distributed in all the fractions was evidenced by the fact that there was neither a concentration of material in any one fraction nor large differences in melting points. The difference of melting point between normal C-15 paraffin and normal C-16 paraffin is only 7° C. The results of the distillation become clear when it is recalled that every hydrocarbon of this molecular weight is separated from its neighbor only by a melting point difference of 0.7° C., considering only normal paraffins to be present in the synthetic wax.

Since a large number of iso-paraffins are also probably present the melting point difference between the individual hydrocarbons becomes increasingly smaller.

4. It can be said that the high molecular weight materials are about equally spread over temperature ranges from low- to high-melting-point material. However, the percentage of material obtained be-

comes smaller as the molecular weight of the fractions becomes larger.

Summary

The results that have been presented together with previous research work have shown that the Fischer-Tropsch synthesis to produce gasoline builds up hydrocarbons of the paraffin series from methane to hydrocarbons of over 150 carbon atoms—quite remarkable since the starting material, carbon monoxide, contains only one atom of carbon. It has been found that these high melting point paraffin hydrocarbons show well over 2000 m.w. and about 117° C. melting point. It has also been shown that an increase in the melting point beyond that stage cannot be obtained even with an increase in the chain length of the molecule. It is worthy of note that the synthesis in this manner of paraffin hydrocarbons by way of carbon monoxide will form hydrocarbons never before isolated in petroleum paraffin waxes.

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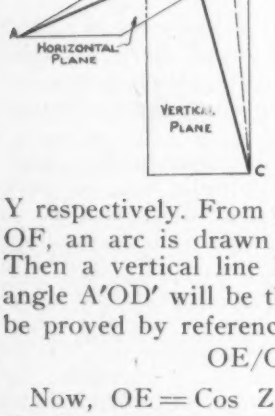
Graphical Method for Finding the Angle Between Lines in Perpendicular Planes

THE problem of finding the angle between pipes which extend in two perpendicular planes, lends itself readily to graphical solution.



Angle Z is the true angle between the two lines.

Cos. Z = Cos. X Cos. Y, as was proven in a previous article (REFINER, July, 1943, p. 213).

Figure 1 is used to derive and explain the graphical method of finding angle Z. The lines OB and OC′ are drawn to form angles X and Y respectively. From point O as a center and radius OF, an arc is drawn to intersect OC′ at point G′. Then a vertical line is drawn from G′ to D′. The angle A′OD′ will be the required angle Z. This may be proved by reference to triangle OCH, in which:

$$OE/OG = OH/OC$$

Now, OE = Cos Z, OG = OF = Cos X, OH = Cos Y and OC = R = 1. Therefore, by substitution, Cos Z = Cos X Cos Y, which shows that angle AOD or Angle A′OD′ is the required angle Z.

Figure 2 solves the problem for the case when X is 30 degrees and Y is 60 degrees. By following the procedure outlined above, that is by drawing in the order named, line 1, arc 2, and line 3, the required angle, Z is found to be approximately 63 degrees.

Figure 3 solves the problem of finding the angle X when angles Y and Z are given. In this case, Y is 40 degrees an Z is 60 degrees. By drawing line 1, arc 2 and line 3, as shown, angle X is found to be approximately 49 degrees.

After angle has been determined, the lengths of pipe required may be readily computed by means of standard formulas.

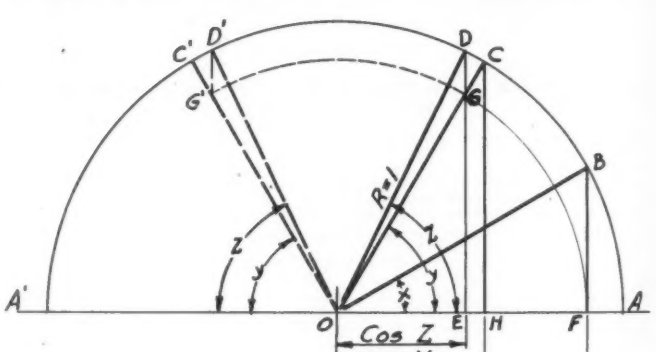


FIGURE 1

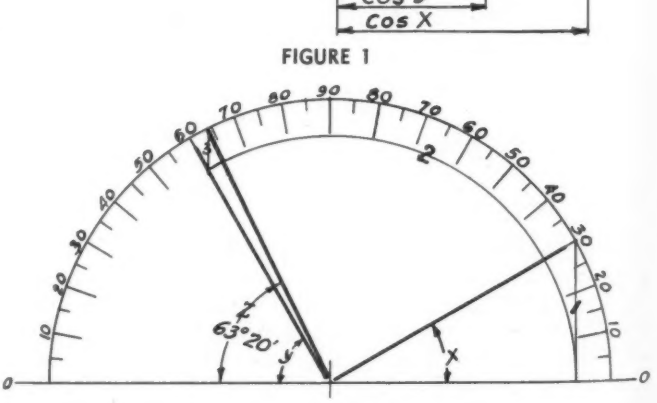


FIGURE 2

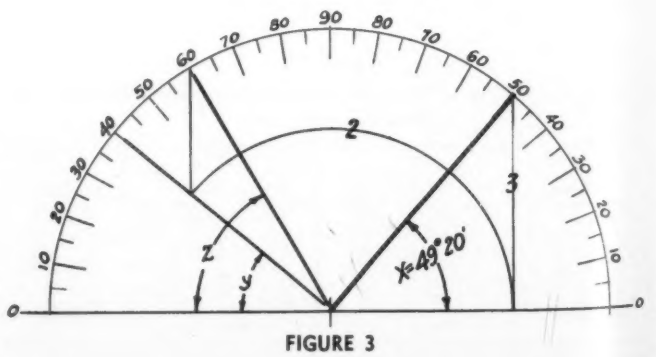


FIGURE 3

Physical Properties of Lubricating Oils at Low Temperatures

ARNOLD BONDI, River Petroleum Corporation

THIS study was made with the purpose of finding a way to characterize the mechanical behavior of lubricating oils at low temperatures in a more satisfactory manner than the heretofore used analytical methods did.

While a number of oils of aromatic or so-called asphaltic type and some of the synthetic lubricating oils do not show any deviation of their measured viscosity from the straight line in the ASTM or Walther-Ubbelohde charts down to the lowest temperatures, the majority of good lubricating oils do show such a deviation from their cloud point temperature on downward. Part 1 of this study will deal with the nature of the cause of these deviations. In Part 7, a number of low temperature viscosity measurements on high grade lubricating oils will be discussed.

Most of the high-boiling petroleum fractions do not solidify in a definite manner, and it is not possible to predict from their general physical data whether they will show glassy solidification or partial crystallization. No technical paraffin wax has a definite melting point, nor are there many distillates or residues the solidification of which were to be described by a steady change of their viscosity. Even the most carefully de-paraffinized oils show crystalline precipitation at extremely low temperatures and bitumina are now also known to separate into resinous and asphaltic matter at temperatures below their softening point.

As the properties of two-phase systems do not obey the same physical laws as homogeneous systems, it is very important to determine the temperature at which the change of a system from the single- to the two-phase state takes place. The following methods have been shown to permit the recognition and measurement of the extent of phase separations in hydrocarbon systems.

a. *The Turbidity.* If the refractive index or the light absorption of the newly appearing and of the surrounding phase are even slightly different, a phase separation will be observed as turbidity. In the case of mineral oil/wax separations, these conditions are mostly fulfilled and the temperature of cloud appearance—in carefully dried oils—is to be understood as the point of change from the normal to the colloidal state. This temperature point gives as little information concerning kind and quantity of the precipitated wax as the initial boiling point gives about the course of a distillation curve. As this point cannot be determined with a high degree of precision in dark colored oils, this test should not be used for the classification of lubricating oils.

b. *Electric Conductance.* As the dielectric and the optical properties of substances are closely related to each other, it should be possible to observe phase separations by electric conductivity or dielectric absorption measurements. Andrew Gemant[10] was the first to publish conductance curves of solidifying mineral oils. These curves are shown in Figure 1. As no further data concerning the solidification of these oils were given in the quoted article, these curves have only a qualitative value in this connection indicating a remarkable resemblance to the conductivity curves of solidifing paraffin wax.

c. *Coefficient of Expansion.* It is well known that paraffin waxes contract considerably during their solidification. It should, therefore, be expected that maxima would be found in the temperature curves of the expansion coefficient of cooling mineral oils at that point where their wax components crystallize. Gurwitsch and Kurnakow[13] already described such phenomena. The author determined the expansion coefficients at a number of temperature points for one of the oils whose mechanical behavior at low temperatures will be described in the second part of this study. (Figure 2.)

d. *Heat of Solidification.* The fourth well-measurable phenomenon accompanying the complete or partial crystallization of any system is the liberation of the heat of fusion. By graphical analysis of the cooling curves (thermic analysis) of solidifying mineral oils, their heat of solidification can be determined[1]:

Theory of the method: If a spherical system is cooled from the outside, the change of temperature with time in the center of the system follows the differential equation.

$$\frac{\partial T}{\partial t} = \frac{\lambda}{c.\rho} \Delta T$$

An approximate integration of this equation gives:

$$\text{Log } (T - T_e) = \text{Log } (T_s - T_e) - \frac{E}{c.\rho} . t$$

That means that a plot of log $(T - T_e)$ vs. time will give a straight line the slope of which is determined by the temperature conductivity of the medium. Any change of the temperature conductivity of the medium occurring in the course of cooling will cause a deviation of the measured curve from the straight line. Liberation of heat within the system in the course of cooling will interrupt the process of cooling and, therefore, bend the cooling curve upward to an extent which depends upon the amount of heat liberated, the temperature range in which that took place, and the thermic inertia of the system under study. Any discontinuity in the cooling curve of a system can therefore be ascribed to the liberation of heat. The procedure for the estimation of the heat of solidification, which will be outlined in the following paragraph, is based on the evaluation

of such discontinuities and was first proposed by Lederer[19], who used it for the determination of the heat of gelation of soap solutions.

Procedure: A spherical flask of 50 to 100 ml. contents is filled with the oil under study, a thermometer is fixed into the neck of the bottle in such a way that the—preferably very small—mercury or alcohol bulb

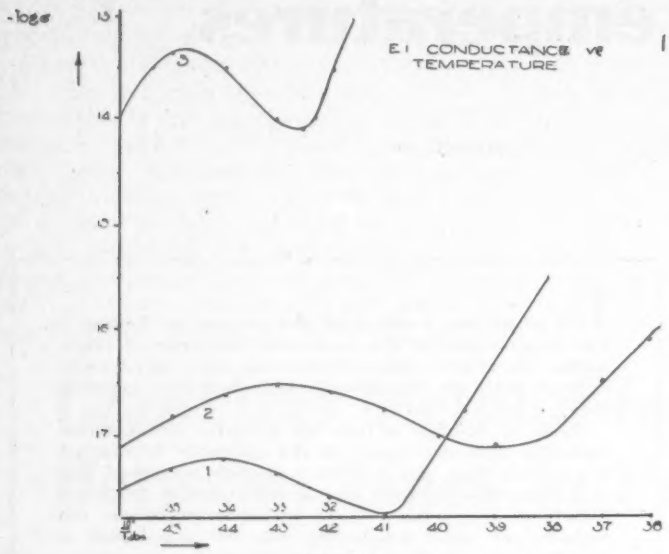


FIGURE 1

Change of electric conductivity of petroleum products with Temperature in the neighborhood of their "solidification point." (From paper by Gemant [10])

Curve 1: Lubricating Oil
Curve 2: Cable Oil
Curve 3: Paraffin Wax (use upper abscissae)

is in the exact center of the sphere. Then, the whole apparatus is placed into a thermostat of a temperature of about 25° C. above the cloud point of the oil until the thermometer inside the flask shows the same temperature as the thermostat. Thereupon, it is quickly immersed in a thermostat of a temperature about 25° C. below the pour point of the oil. The change of the oil's temperature with time is observed every 30 seconds from the moment of immersion. Plotting log $(T - T_e)$ vs. time one obtains a curve of the type A-B-C-D in Figure 3 in the case of wax containing oils, or a curve of the type A-E if no wax precipitation takes place. The heat of solidification is arrived at by multiplying the temperature difference C-F with the specific heat of the oil. In many cases, however, the change of temperature conductivity during solidification is so considerable that corrections have to be applied accordingly. But this question will be discussed in another paper.

In Table 1 heat of solidification data of a number of oils are given. Some of these oils will also be discussed in the second part of this study. Regarding the magnitude of these heats of solidification it may be mentioned that they have to be separated into two parts; the heat of fusion of the crystallizing portion and the "non-ideal" part of the heat solution of that same portion in the mineral oil, out of which it precipitates. From solubility curves of paraffin wax solutions in mineral oils and other hydrocarbons, heats of solution can be calculated which are also higher than the heat of fusion, while in ideal solutions these two data should be equal[22]. With the heat of fusion always taking the greater share of the heat of solidification, the concentration of the crystallizing portion of Pennsylvania motor oils, for instance, can from the data of Table 1 be deduced as being in the neighborhood of 10 percent. As the mechanical behaviour of the solidified oils is much more affected by particle size and character of dispersion of the second phase than by the actual amount of crystallized material which, on the other hand, is determining the magnitude of the heat of solidification, these data have no immediate relationship to the magnitude of the low temperature viscosities. This can best be illustrated by the well-known difference in mechanical properties between the so-called "amorphous" waxes and paraffin wax/oil mixtures of the same melting point and the same heat of solidification. Results of the second part of this study will show that the chemical constitution of the crystallizing phase as well as the influence of the fluid phase on crystal growth are together the main factors determining the degree to which the crystallizing phase will influence the mechanical properties of the system as a whole.

With the exception of the cloud point which indicates the beginning of phase separation, all above described phenomena are not fixed to a certain temperature. The change of conductivity, the solidification contraction, and the liberation of heat of solidification are spread over a more or less wide temperature range. The width of this range is mainly a function of the molecular size distribution of the crystallizing phase, and is only slightly influenced by the boiling range of the fluid phase.

The Low Temperature Viscosity

It is one of the peculiarities of multiphase systems—also called colloidal systems—that data concerning their mechanical properties are meaningless unless the history of such systems has been well defined. The first requirement is, therefore, to form a clear concept of the kinetics of the genesis of that state of the system under study, which exists at the moment at which measurements are taken. A short review of the kinetics of solidification will, therefore, precede the description of viscosity measurements.

a. *The Kinetics of Solidification.* While the velocity of glassy solidification of liquids is very great, and de-

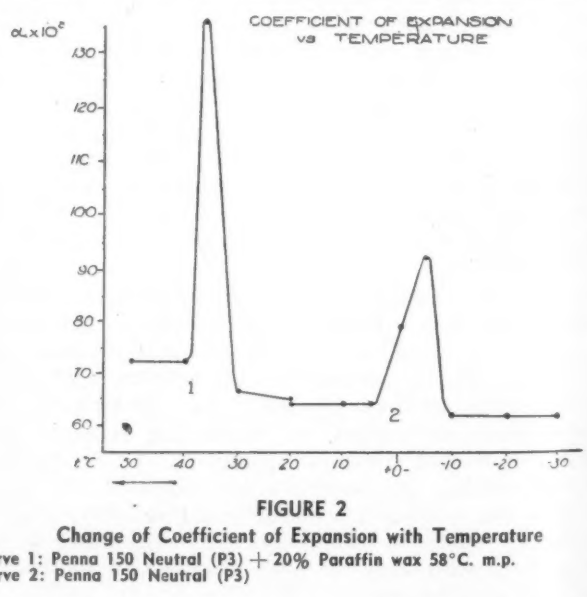


FIGURE 2

Change of Coefficient of Expansion with Temperature

Curve 1: Penna 150 Neutral (P3) + 20% Paraffin wax 58°C. m.p.
Curve 2: Penna 150 Neutral (P3)

pends only on the relaxation time of its molecules, solidification by partial crystallization proceeds very slowly because the velocity of crystallization out of viscous solutions is usually not very great. The velocity of crystallization itself is composed of two parts; the velocity of crystal nuclei-formation and the velocity of crystal growth. The temperature curve of the velocity

TABLE 1

Heat of Solidification Data

SUBSTANCE	Temp. Range of Solidification	Pour Point	ΣH_s cal/g	$\overline{H_f}$ cal/g	$\triangle H$ cal/g
1. Paraffinwax	+51 to +48 °C.	+50 °C.	42	.....	.....
2. 10% No. 1 in 500 Pale	+35 to +16 °C.	+28 °C.	4.5	4.2	.3
3. 10% No. 1 in 300 USP	+40 to +15 °C.	+32 °C.	5.0	4.2	.8
4. Penna. Bright Stock	+15 to + 2 °C.	— 2 °C.	1.6	.....	.....
5. Penna. 150 Neutral	+ 7 to — 8 °C.	— 5 °C.	2.0	.....	.....
6. Penna. SAE 30	+ 8 to — 7 °C.	— 5 °C.	1.7	.....	.....
7. No. 6 +.5% Paraflow	+ 7 to —10 °C.	—16 °C.	1.7	.....	.....
8. Waxy 300 Pale	+15 to + 2 °C.	+ 2 °C.	2.4	.....	.....
9. No. 8 +.5% Paraflow	+13 to + 0 °C.	—27 °C.	2.3	.....	.....

TABLE 2

Dependence of Setting Point of Paraffinaceous Oils on Preheating Temperature

After Kreulen (18)

Preheating Temp. °C.	30	35	40	45	50	60	70
Setting Point °C.	12	13	17	22	25	25	4

TABLE 3

The Structure Effect

	300 VISC. MEDICINAL WHITE OIL PLUS			
	.5% 52 m.p. Paraffin-wax		.5% 52 m.p. Ozokerite	
	As Is	+ Paraflow	As Is	+ Paraflow
Visc. @ 0 °C. calc. from Einstein's equation	13.1	13.1	13.1	13.1 Poise
Visc. @ 0 °C. experimentally	24.6	14.4	38	16.2 Poise

TABLE 4

Variation of "Viscosity" with Applied Shearing Stress, Substance: Penn SAE 30 Oil

SHEARING STRESS	VISCOSITY AT °C.				
	0	—5	—10	—15	—20
.33 kg cm $^{-1}$ sec $^{-2}$	21.7	111	1130	.....	..... Poise
4.40 kg cm $^{-1}$ sec $^{-2}$	18	47	216	1820	22,000 Poise

TABLE 5

Low-Temperature Viscosity of Wax Solutions

SUBSTANCE	VISCOSITY AT °C.					
	0	—5	—10	—15	—20	Applied Shearing Stress
1. USP White Oil 300	11.6	18.6	33.1	59	192 Poise	.3 kg cm $^{-1}$ sec $^{-2}$
2. No. 1 + .5% Par. Wax	24.6	64	124	320	1340 Poise	.3 kg cm $^{-1}$ sec $^{-2}$
3. No. 2 + .5% Paraflow	14.4	24.4	46	87	160 Poise	.3 kg cm $^{-1}$ sec $^{-2}$
4. No. 1 + .5% Osokerite	38	64	205	630	3500 Poise	.3 kg cm $^{-1}$ sec $^{-2}$
5. No. 4 + .5% Paraflow	16.2	28	58	110	227 Poise	.3 kg cm $^{-1}$ sec $^{-2}$
6. No. 1 + 10% Vaseline	16.6	29.2	54.7	93	200 Poise	4.0 kg cm $^{-1}$ sec $^{-2}$
7. No. 1 + 5% Cyl. Stock	13.6	26.3	52.1	100	203 Poise	4.0 kg cm $^{-1}$ sec $^{-2}$
8. No. 7 + .5% Paraflow	13.3	22.3	38.6	79	156 Poise	4.0 kg cm $^{-1}$ sec $^{-2}$

TABLE 6

Viscosity Increase Caused by Chilling

SOLUTION	VISCOSITY AT —20 °C.	
	Cooled Slowly	Chilled
1. USP 300 + .5% Ozokerite	3,500	10,500 Poise
2. No. 1 + .5% Paraflow	227	3,700 Poise
3. USP 300 + .5% Paraffine Wax	1,340	6,500 Poise
4. 500 Pale Oil	650	11,000 Poise

TABLE 7

Comparison of Efficiency of the Components of Paraflow

SUBSTANCE	VISCOSITY AT °C.		
	0	—5	—10
P8R	20.9	50.4	942 Poise
P8R + .5% Paraflow	14.5	24.2	46.7 Poise
P8R + .08% "active ingredients" of Paraflow	17.8	34.4	80.0 Poise
P8R + .42.. "inert materials" of Paraflow	24.7	186	Poise

TABLE 8

Low-Temperature Viscosity of Diluted Oil

SUBSTANCE	VISCOSITY AT °C.						
	+100	0	—5	—10	—15	—20	—25
P 8	.10	18.5	47	216	1820	22,000	Poise
P 8 + 10% Kerosine	.07	6.5	13.2	20	.....	58	134 Poise

TABLE 9

Correlation of Pour-Point and Low-Temperature Viscosity

OIL	VISCOSITY AT °C.		
	+50	—15	Pour Point
P 8	60 cSt	1820 Poise	— 5
P 8 R	58 cSt	3330 Poise	— 4
P 8 R + .5% Paraflow	58 cSt	103 Poise	—12
Motor oil 500	57 cSt	626 Poise	—20
Motor oil 12	91 cSt	252 Poise	—12
Motor oil 12 P	88 cSt	392 Poise	—15
R 12 R	85 cSt	7440 Poise	+ 2
R 12 R + 1% Paraflow	85 cSt	626 Poise	—15

TABLE 10

Correlation of Interpolated and Measured "Lowest Starting Temperature"

	SPECIMEN			
	P 8	P 8 R D	P 8 R P	M 12
Lowest Starting Temperature, interpol., °C.	—1	— 5	— 9	—2
Lowest Starting Temperature, measured, °C.	—8	—14	—15	—9

Physical Properties of the Lubricating Oils Under Study

	P-35-R	P-3-R	P-8-R	P-8	R-12-	R-12-R	PL-30
Spec. Grav. a 20 °C.	.879	.851	.865	.887	.905	.883	.882 (g cm^{-3})
Visc. a 20 °C. cSt.	1,344	67.3	281	338	765	567	224 (cm ^{2} sec $^{-1}$+10 $^{-2}$)
Visc. a 50 °C. cSt.	196	18.4	58.4	60.5	91.5	85	39.8 (cm ^{2} sec $^{-1}$+10 $^{-2}$)
Visc. a 80 °C. cSt.	54.7	7.7	20.0	19.0	24.0	25.0	13.5 (cm ^{2} sec $^{-1}$+10 $^{-2}$)
Pour Point °C.	-4	-3	-4	-5	-10	+1	-19
Aniline Point °C.	131	108	.....	.....	110	118	108
Conr. Carb. Res. Percent	.46	.....	.30	.60	.08	.06	.02
Visc. a —15 °C. Poise	15,000	98	3,300	1,820	1,000	7,440	59 (g cm $^{-1}$ sec $^{-1}$)
dto. deparaffinised	(4,700)	(13)	(665)	.....	.....	(1,450)	.....
dto + Paraflow	.....	.....	(103)	(170)	(405)	(626)	.....

NOMENCLATURE

c = specific heat (cal g^{-1} °C^{-1})
H_s = total heat of solidification (cal g^{-1})
H_f = partial heat of fusion
H = non-ideal part of heat of solution (cal g^{-1})
T = Temperature (°C)
T_e = Temperature of cooling medium (°C)
T_s = Temperature of oil before cooling (°C)
η = Dynamic viscosity, Poise, (g cm^{-1} sec^{-1})
ν = Kinematic viscosity, Stokes, (cm^2 sec^{-1})
λ = Heat conductivity (cal cm^{-1} sec^{-1} °C^{-1})
q = Specific Gravity (g cm^{-3})

of crystal-nuclei formation of pure compounds has been shown to pass through a maximum (which need not necessarily be the melting point of that substance[9, 25]). In mixtures like lubricating oils, this maximum is not very likely to be very pronounced, because with each degree temperature lowering another group of compounds of successively lower melting point tends to

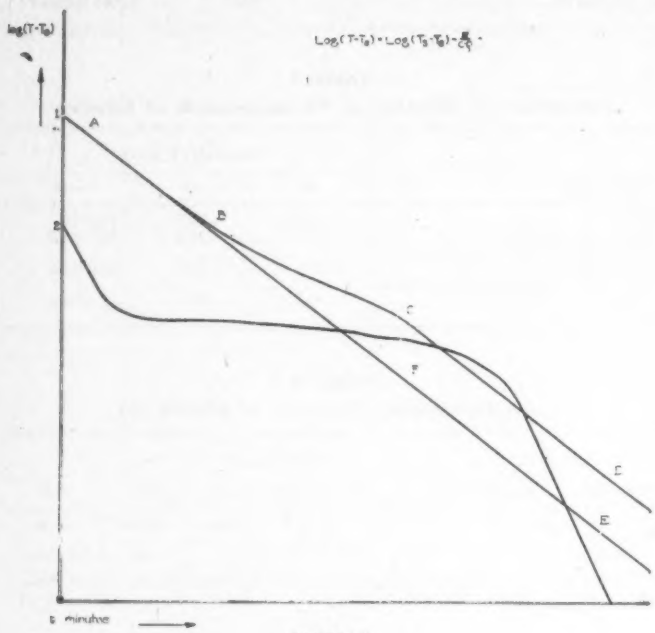


FIGURE 3

Thermic Analysis of Solidifying Lubricating Oil

Curve 1: A-B-C-D Penna Lubricating Oil (P8)
Curve 2: Paraffin Wax 42°C. m.p.

crystallize, and all these curves will superimpose each other to result in a steady increase of the velocity of crystal-nuclei formation with decreasing temperature until a constant value will be reached. The temperature curve of the velocity of crystal growth, also, goes through a maximum, and although, in this instance, too, the wide distribution of melting points of the crystallizing fractions in lubricating oils is flattening that maximum, it is readily discernible in the pour point/preheating temperature curves of Kreulen[18] and Sachanen[21] (Table 2). In these experiments, the oils were, for a certain length of time, kept at the "preheating temperature," and then cooled down to the pour point at a standardized rate.

The decrease of crystal growth velocity explains also another phenomenon; the "plasticity" of most lubricating oils after chilling them. Namely, on sudden cooling, great numbers of small crystals are formed because of the low crystal growth velocity at low temperature[17, 30]. (See Erk's Photographs, Figure 4.) Judging by the microscopic appearance of rapidly chilled oils, it seems justified to assume the crystals in them to be small enough to come within reach of the Brownian movement. According to the Einstein-Smochulowski theory of the Brownian movement the average deviation of small particles out of the normal position is inversely proportional to the square root of their radius[9] and, furthermore, as the number of particles which can be made out of a certain amount of matter varies inversely as the cube of the particle's diameter, it follows that the collision probability of particles increases rapidly with diminishing particle diameter. As there is always a certain probability that particles which have collided will stick together, it is evident that sudden cooling—producing very small crystals—causes a more homogeneous and quicker build-up of gel-structure than slow cooling, where bigger crystals are formed.

An illustration of the resulting plasticity is given in Figure 5, representing the appearance of the surface of chilled lubricating oil flowing through a capillary of 4 mm. diameter as it has been observed by the author. It is quite obvious that these chilled oils show all of the peculiarities of "plastic flow"[12] with the whole liquid column sliding like a solid piston through the capillary without leaving any oil adhering to the walls. True liquids at comparative "viscosities" and the same flow speed leave such an amount of liquid adhering to the walls, that viscosity measurments on such liquids can only be performed upward through a capillary.

b. *Viscosity Measurements.* While in the course of glassy solidification, the "normal" viscosity/temperature relations and the Poiseuille law remain valid up to the highest viscosities, the most curious phenomena can be observed in colloidal systems. Being one of the most characteristic properties of those systems, their viscosity has been studied very intensely for more than 40 years. As all published investigations of solidifying mineral oils[4, 6, 16, 17, 24, 27, 29], as well as the author's own experiments did not reveal the existence of phenomena which are not already known from much simpler systems, no effort was made to give a complete picture of all specifically colloidal properties of solidifying mineral oils. Much effort was, in fact, directed towards avoiding interference of elasticity and plasticity phenomena with viscosity measurements by resorting to the application of high-shearing stresses.

Experimental Procedure

The herein described viscosities were measured in the Vogel-Ossag Viscosimeter[7]:

As it frequently happened that the compressed air drilled a hole through the solidified oil, an oil storage vessel without overflow was used to offer a bigger oil surface. Capillary tubes of 4 mm. diameter were used and pressures in the range of 40 to 50 cm. mercury applied in order to work in that part of the efflux/pressure curve where it is a straight line. The cooling rate was about 5° C. per hour between all measurements of one curse. The oil flow during measurement was always upward, in order to avoid incorrect results caused by the slow draining of the capillary walls or even by the drilling of holes all the way through the oil by the compressed air. The construction of the Vogel-Ossag viscosimeter allows the removal of the capillary after draining back and cleaning from the adhering oil before the next run. The only other alternative would have been the construction of a capillary with several bulbs above each other to be used successively as has been proposed by Fenske and collaborators[2, 3, 8]. But the oil-storage vessel of the Vogel-Ossag viscosimeter does not contain sufficient oil to supply more than 2 to 3 cc. of oil at extremely high viscosity values without blowing through. From all experiences gained so far, it seems advisable anyhow to continue these measurements with Couette viscosimeters (after adaptation to low-temperature work) and eventually standardize that type viscosimeter for the low-temperature part of the viscosity-temperature curve.

Presentation of Data

Viscosity determinations on wax free oils down to —25° C. proved the validity of the relation[31]:

$$m = \frac{W_1 - W_2}{\log T_2 - \log T_1} \qquad (3)$$

where $W = \log \log (cSt + 0.8)$

even in the low-temperature range, giving a straight

line for the viscosity-temperature curves of such oils on the Walther-Ubbelohde chart or the ASTM chart. These findings permitted to presume the above relation to hold for any oil provided it did not show phase separation. Taking then the low-temperature extrapolated values of the normal viscosity line of an oil as basis, the ratio of the actually determined viscosities to those extrapolated ones should give a very good picture of the extraordinary behaviour of wax containing oils at low temperature. Graphs of these ratios on semilogarithmic scale (Figure 6) will form the basis of discussion in the following paragraphs. One of the advantages of this mode of presentation is the sensitivity with which the effects of refining operations on the low-temperature viscosity are recorded thereby, independent of the magnitude of the absolute viscosity of any oil. From these graphs it will be realized that the low-temperature viscosity curve is so dependent upon the individual refining history or compounding of any oil, that a general mathematical formula of the function $LTV = f(T)$ cannot be expected to exist. Another advantage of this method is its scientific soundness, being that it is based on the experimentally-proven validity of the empirical equation (3) within the observed temperature and viscosity ranges for precipitate-free oils, and on a physically defined and reproducible determination procedure and not on any ill-defined and arbitrary testing method of which there are still so many used for the characterization of petroleum products.

FIGURE 4

Wax crystal growth at Various Cooling Rates. (From paper by Erk [6a]).

(a) Wax Distillate cooled slowly from 50°C. to 20°C.
(b) Same Distillate chilled suddenly from 50°C. to 20°C.
(Magnification 120 X)

c. *Results*

It has been indicated above that the low-temperature viscosity consists of two parts; the viscosity of the fluid phase, and the viscosity increasing effect of the dispersed solid phase. If these solid particles would swim in the oil without touching each other, the ratio η/η' could approximately be related to the amount of precipitated wax by the Einstein formula $\eta/\eta' = 1 + 2.5$ or one of its modified forms[11]. A comparison of such viscosimetrically determined amounts of precipitate with the amount computed from heat of solidification data shows that the viscosity increase effected by the wax precipitate is, in almost all cases, very much greater than could be explained from the concentration of solid particles alone (Table 3). This can only be interpreted to mean that the precipitated wax crystals interlocked to form a structure the rigidity of which is measured as "viscosity." The amount η/η'—1—2.5 therefore indicates the resistance of that structure to shearing stress. Contrary to the properties of continuous solids, the resistance of this structure is not independent from the applied force, but diminishes with increasing shearing stress (Table 4) approaching asymptotically a constant value which latter alone will concern us in the following discussions as in all technically important applications, motor lubricating oils are subjected to shearing stresses which are in the region of 2 kg cm^{-1} sec^{-2} and higher.

Effects of Chemical Composition, Refining Processes and the Admixture of Pour Point Depressants on the Low Temperature Viscosity

Before the study of the effect of refining processes and additives was started, a number of model solutions were prepared in order to learn from results obtained under simplified conditions how to interpret the results of such complex systems as would be encountered in the refinery. These model solutions were prepared from medicinal white oil and paraffine wax or ozokerite. Paraffine wax was to show the effect of "macrocrystalline" precipitates, and ozokerite those of "microcrystalline" precipitates. The resulting low-temperature viscosities were, however, so much out of proportion in comparison to the viscosities of actually occurring systems, that further experiments with such model solutions were abandoned. It would, nevertheless, be interesting to find out why high-melting waxes increase the low-temperature viscosity so much more than natural wax mixtures of the same contents of high-melting wax. The results of this abandoned project are tabulated in Table 5.

The effect of solvent refining, deparaffinization, and pour-point depressants on the low-temperature viscosity of a number of oils have been assembled in the graphs of Figure 6. The effect of all three of these manipulations on a Pennsylvania SAE 30 oil can be read from Figure 6a. Curve 4 belongs to the unrefined oil P8 made up from standard Pennsylvania bright stock and 150 Pennsylvania neutral oil, while Curve 1 belongs to oil P8R which is a mixture of the same bright-stock and neutral oil after their extraction with nitrobenzene. Below —10° C., the viscosity of the solvent-refined oil increased at such a steep rate that measurements had to be discontinued below —15° C. Curve 3 shows the data of oil P8R after dewaxing by the acetone-benzene method at —10° C. Although the viscosity de-

crease through dewaxing is quite considerable, it seems remarkable how quickly the dewaxing effect is lost at temperatures below the dewaxing temperature. Curve 2 demonstrates the advantage of pour-point depressant addition over dewaxing. This curve also proves that "artificial" depressing of the pour point is not only not a means of deceit, but gives such treated oils the

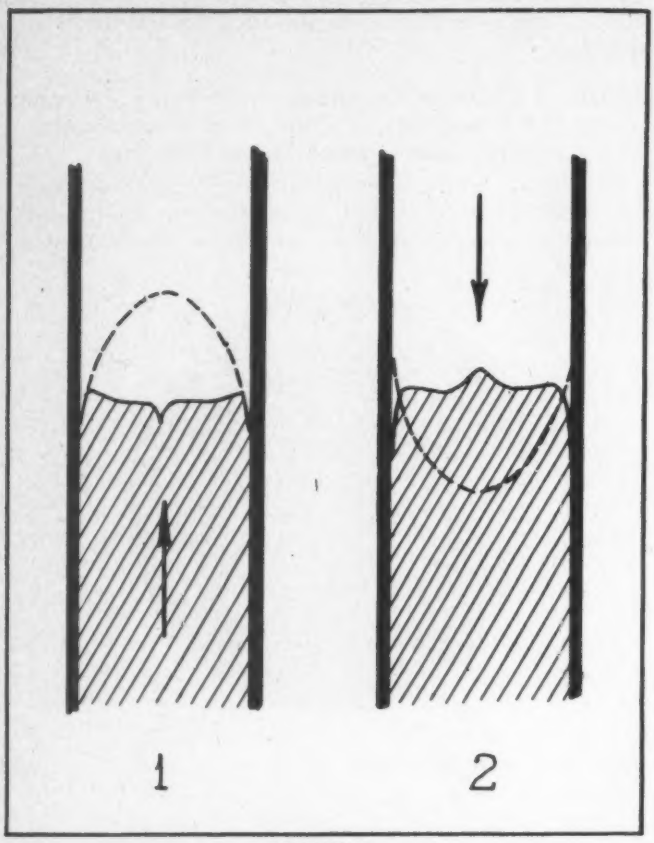


FIGURE 5

Anomalous flow of chilled lubricating oil through viscosimeter capillary.

Appearance of oil chilled suddenly 5°C. below pour point and being forced upward (1) or downward (2) through 4 mm. ID capillary. Broken lines indicate appearance of oil of comparable viscosity flowing at the same velocity.

distinct advantage of not exhibiting abrupt increases of viscosity below a certain temperature as is so peculiar for dewaxed oils. It seems, therefore, advisable to add pour-point depressants even to dewaxed oils to guard its user against disagreeable surprises at extremely low temperatures. Figure 6b combines the curves of P35R, P35RD, P3R and P3RD, the components of P8R and P8RD respectively. There is nothing especially remarkable about these curves ouside of the fact that the nice straight line of P35R which seems to be peculiar to untreated oils of medium and high viscosity. Figure 6c represents the curves of a specially refined diesel lubricating oil DR12 as is, dewaxed, and after addition of pour-point depressant. The dewaxed oil DR12RD shows the expected pattern: low viscosity until dewaxing temperature and then, the abrupt increase obliterating all dewaxing effects within the next 5- to 10-degree temperature lowering. Here again doping with pour-point depressant proves to be the superior method, Curve DR12RP laying just between the other two curves down to —10° C., but keeping well below either one of them in the lower-temperature regions.

Theory of the Pour-Point-Depressant Effect

The theory seems well established that pour-point depressants act by being absorbed on the newly formed crystal surfaces and thus, prevent the formation of a cohesive structure by preventing the wax crystals from sticking to each other.[4, 32, 33] Therefore, almost all oil-soluble surface active agents could be used as pour-point depressants if most of them would not at the same time promote the deterioration of lubricating oils by catalysing its oxidation. In addition to the already known base of the adsorption theory of pour-point depressants, the observation might serve as another proof that the heat of solidification remains practically unchanged after the addition of Paraflow, for instance, while pour point and viscosity decrease considerably. This would not be the case if pour-point depressants acted by keeping the otherwise crystallizing wax in solution, because then the heat of solidification should be markedly decreased. The "adsorption theory" also explains why Paraflow cannot prevent the above mentioned tremendous viscosity increase which is caused by chilling. It was explained above that on sudden cooling, the wax separates in the form of a great number of small crystals. These must have a larger total surface than the same amount of wax would have if crystallized in bigger crystals. Assuming the slowly cooled paraffine crystals of solution No. 1 in Table 6 had a side length of .1 mm., their total surface in 100 g. solution were about 400 cm^2. In the case of sudden cooling, the size of the paraffine crystals may be assumed to range from 1 to 10μ. Their surface would be .4 to 4 m^2. The "active" part of 100 g .5 percent Paraflow solution spread as a mono-molecular layer would cover 2 m^2 at best. It is, therefore, evident that even if the total amount of surface-active ingredients would be adsorbed—which is very improbable—structure formation could not altogether be prevented. It might be mentioned in this connection that Paraflow can be separated into two fractions by selective adsorption on fuller's earth out of its petrol ether solution. Table 7 shows that the non-adsorbed fraction—83 percent of the product—is a yellow oil which has no effect on either the pour point or the low-temperature viscosity. The adsorbed fraction after having been extracted with $CH\,Cl_3$—17 percent of the product—however, seems to constitute the "active ingredients" of Paraflow as it has almost the same effect as the equivalent amount of Paraflow. The slight impairment of the efficiency of the "active ingredients" can be traced to oxidation reactions in the course of the isolation procedure. A few improvements—like eluting and distilling in nitrogen atmosphere—will make this isolation procedure, which has been described in detail elsewhere[23], reliable for the determination of the concentration of active ingredients in pour-point depressants and other surface-active materials. This method also suggests the possibility of isolating pour-point depressants out of certain petroleum fractions by selective adsorption. Preliminary investigations in this direction revealed, however, that a number of other factors have to be considered aside from surface activity in order to obtain a good pour-point depressant. But, in view of the present scarcity of the raw materials going into Paraflow, the development of some such new source of supply might be of importance.

The widespread practice of adding small amounts of kerosine to lubricating oils under conditions of extreme cold weather was also investigated as to its actual effectiveness. The results, tabulated in Table 8, prove this method of depressing the low temperature viscosity to be really most efficient. It need hardly be emphasized how dangerous this dilution procedure can

be for the motor, if it is not performed with extreme caution. Only oils of high viscosity index should be subjected to such winter dilution, as these are less susceptible to viscosity decrease by dilution than the low-viscosity-index oils.

c. *Testing Standards*

The generally used test for the characterization of the behavior of lubricating oils at low temperature is still the pour point. It is unnecessary to say how misleading such a characterization can be, and Table 9 was only put in here to illustrate this fact once more. High-viscosity-index oils, especially, might show differences in pour-point data which will not at all be related to their low-temperature-viscosity curves. This lack of relationship is mainly caused by the fact that only gravitation is forcing the oil to flow in the pour point procedure while in the above described viscosity determinations, application of forces exceeding more than 100 times the gravitational forces were found necessary to get results consistent with field conditions. The U-tube methods for the determination of the setting point[5, 14, 19, 15] which approach viscosity measurement in principle are afflicted with two sources of misrepresentations: 1. The cooling rates specified in most testing are so high as to cause chilling, and 2. The transpiration pressure applied is much too low in all cases. The importance of sufficient transpiration pressure has already been emphasized above. The cold-test instrument of the German army procurement office[20, 24] comes nearest to reproducing the shearing stress conditions in a starting motor. It consists of a sleeve bearing suspended in a refrigerating chamber. The time is measured during which the shaft of this bearing performs a specified number of revolutions under an application of a certain force. It is, in other words, just a fairly accurate viscosimeter involving the additional expense of a refrigerating chamber. Besides the expense, there are two flaws inherent in the use of a refrigerating chamber: 1. Because of its thermal inertia, it can only successfully be used at one constant temperature. 2. This will of necessity be the lowest temperature expected to be encountered in actual use. The oil will, therefore, be chilled and results are frequently not reproducible. Minus 30° C. has been chosen by the German army procurement office as standard temperature. The viscosity value obtained at this temperature is marked on the viscosity temperature chart and a line is drawn connecting it with the oil's viscosity at plus 20° C. The temperature at which this line intercepts the 110 Stokes (about 50,000 SSU) line is called the "starting value" of the examined oil. 110 Stokes has been found to be the upper viscosity limit for satisfactory starting performance of a number of car motors in a refrigerating chamber. This interpolation is a quite unreliable procedure and might lead to considerable undervaluation of certain oils if compared with actual measurement as can easily be seen from Table 10.

Based on the conclusions which can be drawn from the results of this investigation, a testing and evaluating procedure for the characterization of the low-temperature behavior of lubricating oils is proposed as follows: Viscosity measurements at low temperature should be performed under shearing stresses of at least 2 kg cm^{-1} in high pressure capillary viscosimeters or Couette type viscosimeters. Rates of shear should, in both cases, never be so high as to cause building up of a temperature gradient of more than .5° C. from the center of the oil layer to the capillary or cylinder walls, by inner friction, a limit which is easily reached in highly viscous liquids of low heat conductivity[28]. In the case of capil-

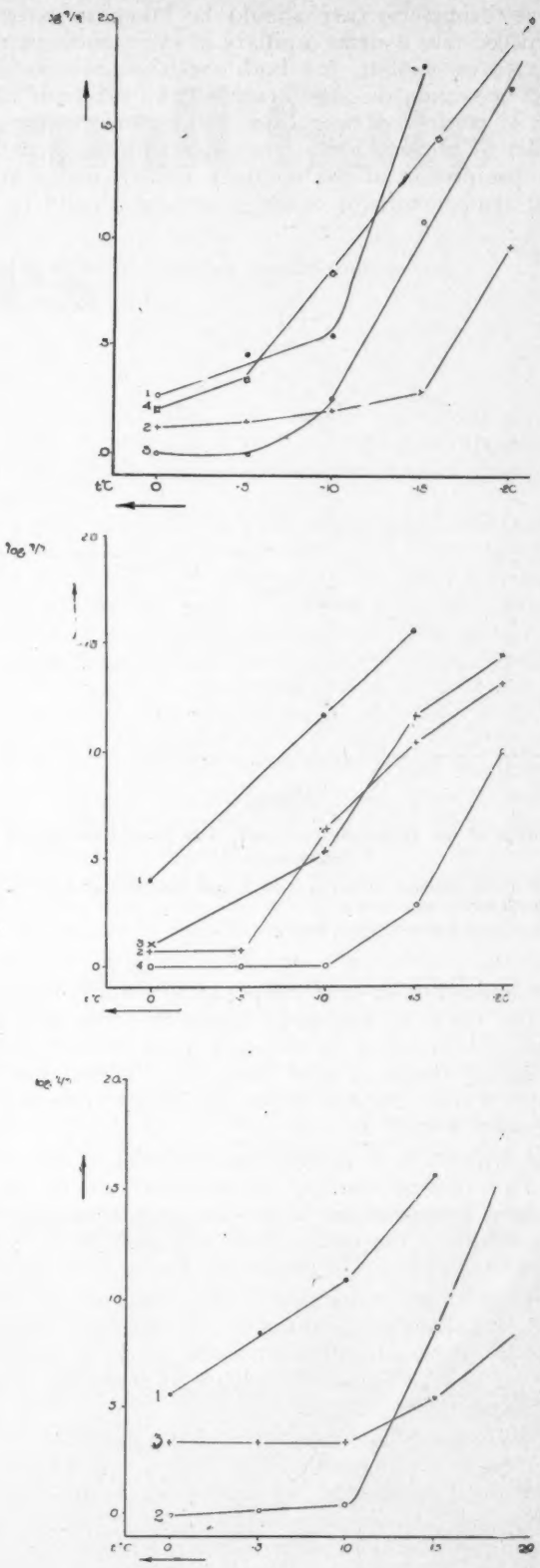


FIGURE 6

Low temperature viscosity characteristic of lubricating oils.

μ = actual viscosity, Poise (g cm^{-1} sec^{-1})

μ^1 = extrapolated viscosity from logγ—plot (ASTM or Ubbelohde—Chart) converted into Poise.

(a) Curve 1: Oil P 8 R
Curve 2: Oil P 8 R P (cont.—5% Paraflow)
Curve 3: Oil P 8 R D (dewaxed at —10°C.)
Curve 4: Oil P 8

(b) Curve 1: Brightstock P 35 R
Curve 2: Brightstock P 35 R D (dewaxed at —10°C.)
Curve 3: 150 Neutral P 3 R
Curve 4: 150 Neutral P 3 R D (dewaxed at —10°C.)

(c) Curve 1: Russian Diesel Lubr. Oil D R 12 R
Curve 2: Russian Diesel Lubr. Oil D R 12 R D (dewaxed at 10°C.)
Curve 3: Russian Diesel Lubr. Oil D R 12 R P (cont.—1% Paraflow)

lary viscosimeters, care should be taken to have the oil proceed into a clean capillary at every measurement. The rate of cooling for both types of viscosimeters should be standardized at about 10° C. per hour above —10° C. and 5° C. per hour below that temperature in order to prevent chilling of more paraffinaceous oils. After completion of the viscosity measurements at the lowest temperature of a series, the oil should be left

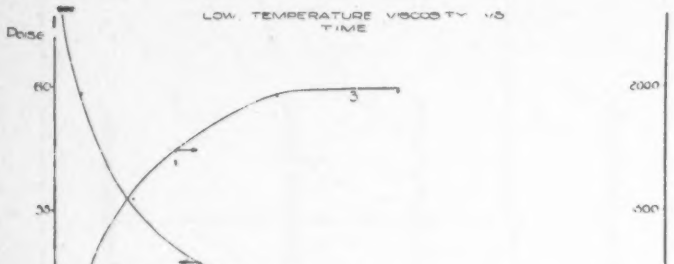


FIGURE 7

Change of low temperature viscosity with time. (From thesis of Jordachescu [17]).

Curve 1: Penna Motoroil chilled to —80°C. and then kept at 0°C.
Curve 2: Same oil kept at 0°C.
Curve 3: Oil of unknown origin kept at —5°C.

in the apparatus at that temperature for 24 hours and then the viscosity measured again as some oils show considerable increase in viscosity after prolonged cooling, and 24 hours is most likely the longest time that a motor will be exposed to the low temperature without being used. Figure 7.

The evaluation of results would consist of two parts:

1. The "lowest starting temperature" would be obtained by interpolation of the curve of measured viscosity values as the temperature at which the oil would show a viscosity of 110 Stokes or 50,000 SSU.

2. The "low-temperature-characterization curve" would be calculated by dividing the measured viscosity values by those found by extrapolation of the viscosity curve on the ASTM or Ubbelohde chart to the respective temperature.

Very valuable additional information would be obtained from the determination of the response of the viscosities at extremely low temperatures and the viscosity at 100° C. to dilution by 10 percent of a standardized kerosine. In the case of winter oils, the usual data sheet would then be supplemented by the following data:

Lowest starting temperature.....
Lowest starting temperature after dilution.....
Viscosity at —15° C., —30° C.....
Viscosity at —15° C., —30° C. after dilution.....
Viscosity at 100° C.....
Viscosity at 100° C. after dilution.....

Summary

In the first part of this study, a number of methods were described which allow us to find out whether, and in which temperature range, a phase separation occurs in mineral lubricating oils. Some of the phenomena observed closely resemble phenomena peculiar to solidifying paraffin waxes, such as melting-point contraction, heat of solidification, and maxima in electrical conductivity temperature curves. These similarities, however, can only serve to prove that the observed phase separation in lubricating oils is due to partial crystallization, but they did not prove that the crystallizing phase is paraffin wax. The viscosity effect of added paraffin wax exceeded the effect of the naturally occurring crystallizing material by one order of magnitude.

The second part of this study, concerning itself with the mechanical behavior of lubricating oils at low temperatures was introduced by a discussion of the kinetics of solidification. The velocity of solidification was found to consist of several velocity components. Of these, only the velocity of crystal growth was observed to be of practical significance. Its extremely low values at low temperatures could be held responsible for the occurrence of plastic solidification of lubricating oils under conditions of rapid chilling. Based on this knowledge, rigid standards for the rate of cooling for low-temperature-viscosity measurement were adopted in order to obtain reproducible results. As the apparent viscosity of two-phase systems is known to be a function of the applied shearing stress, all viscosity measurements were conducted under application of shearing stresses comparable to those in motor bearings, in order to obtain viscosity values of practical significance. A new method of graphical presentation of low-temperature-viscosity data permitted the study of the effects of refining, dewaxing and pour-point depressants in detail. Such a close investigation revealed that the addition of pour-point depressants is of much greater importance for the low-temperature performance of lubricating oils than has been generally known heretofore. In many instances, the effect of pour-point depressants surpasses the improvement wrought by dewaxing, and it has been found highly recommendable to mix additives even to dewaxed oils.

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Reviewing Small Gate Valves

BY CONSTANTLY improving its method of rebuilding small gate valves one large refining company on the West Coast has arrived at a point where it gains full value of these parts. Small valves, bronze and brass, ⅛- to 2-inch, make up the major portion of the valve requirement in plant operation. Consequently wear, breakage and corrosion result in constant accumulation of worn valves.

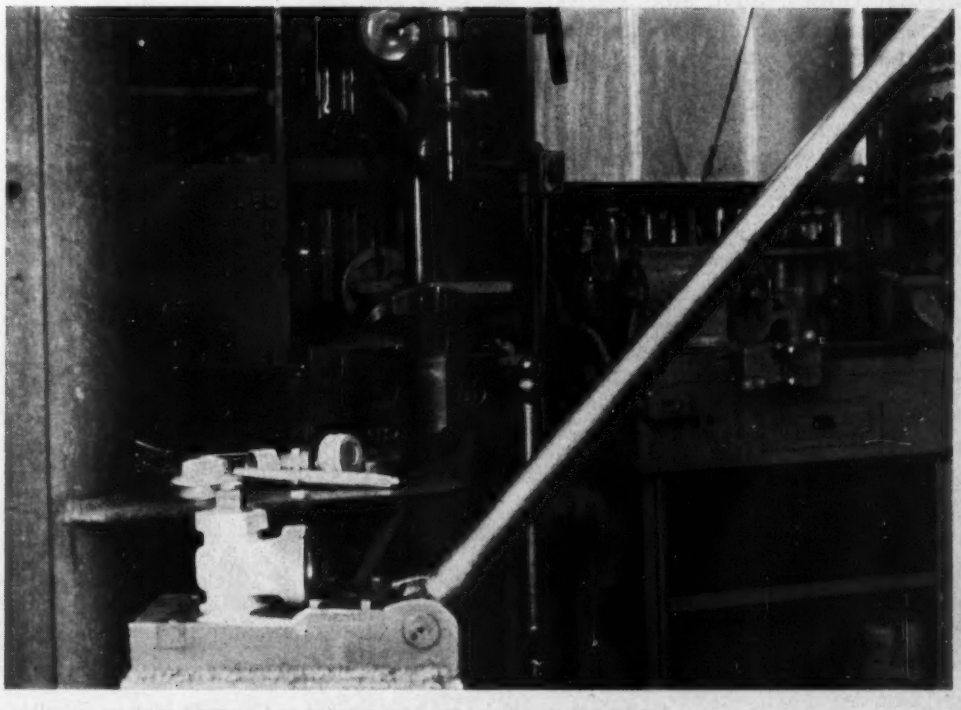
The system of rehabilitation involves the customary segregation at plants and periodic delivery to the salvage depot. After dismantling each valve, its parts are strung together on a wire and as many as 50 dismantled valves are immersed in a cleaning solution, then steam rinsed. This is followed by an acid bath, another rinse and then immersion in a "brass dip," a chemical solution which restores original bright color. This is an aid to visual inspection.

The valves are segregated on the basis of type and manufacture as an aid to reassembly. First comes inspection of stems. Those only bent are repaired. Broken stems are replaced from new stock or from new stems made by turning down stems from larger valves. Then all parts are subjected to a wire brush to remove any remaining foreign matter.

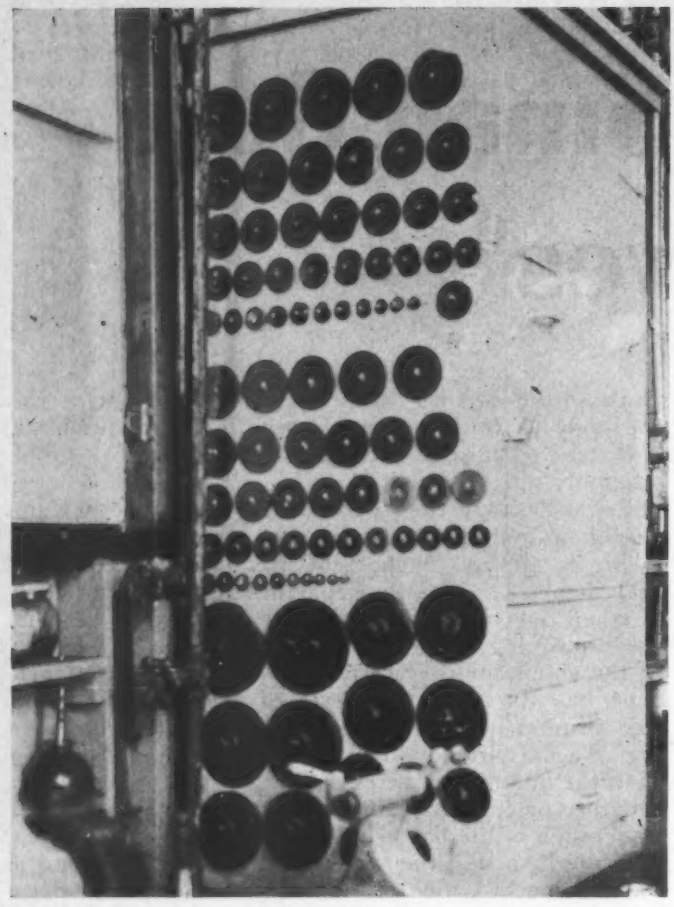
Special tools have been designed for regrinding bodies and seats. If the valve has a ground joint fitting to the body, two tools are required for resurfacing, a concave device with a sheet of abrasive cloth to smooth the body and a convex device for the body. A few turns with grinding compound are sufficient to lap parts together and assure leak-proof assembly.

Regardless of the type wedge seat, whether inserted or manufactured integral with the body, refacing is almost 100 percent accomplished with the seat in place. The only departure from this practice is when one or both insert seats is damaged beyond reconditioning. Special tools have been developed in the shops for this purpose and each size and each type has its individual style of refacing tool. The seat grinder is made of three pieces of steel, consisting of a flat circular plate slightly larger in diameter than the outside diameter of the seat surface, and two separate pieces as auxiliaries. The part which fits the under side of the flat grinding plate has a head which fits snugly inside the wedge without binding, and a narrow neck which fits snugly inside the wedge without binding, and a narrow neck which passes through a center hole in the wide plate. The other is a screwdriver-slotted capscrew-type which passes into the lower part through a tapped hole threaded to receive it.

Circular pieces of abrasive cloth are employed for grinding the wedge by inserting one between the wedge guide and the flat plate and retained by holding in place with the threaded upper part. A tapered



The valve renewal shop is equipped with a compression tool, which has adapters to fit any size hexagon end of small valves. This permits resizing the threaded section of fittings.



Wedge seat grinding plates were designed and made in the department which handles renewal of small valves. The assortment permits work on any make or type of small valve.

piece of hardwood is laid on the drill-press table to bring the wedge seat face at right angles to the screwdriver bit in the drill press. The operator controls the speed and pressure of grinding to produce a smooth finish on the wedge seat without heavy circular ridges. Each size and type of valve has its corresponding grinding plate which is used only for that particular valve.

As the distance between the seats is established when the valve is first made so that the wedge will not extend through to the body, grinding of both wedge and seat widens this distance until a correction must be made. After the valve is assembled, repacked and just before testing, it is placed in a special press, developed in the shop for this purpose, which is made so that the operator can exert a pressure with a long handle. The wedge is run down almost to the point of operation and the valve body placed endwise in the press so that it can be compressed to renew the distance between the seats. The right pressure and position of the wedge is controlled by the operator after gaining enough skill to compress the body and not mar either the wedge or the seats.

This valve receives another operation immediately following, which is to compress the threaded end to a slightly undersize to compensate for expansion caused by making up on the pipe. Two steel plugs are employed, threaded to a slight undersize from standard for the threaded end, one placed in each opening. Adapters exactly fitting the hexagon ends are placed in the press and the valve end inserted so that each face received a sharp blow by swinging the press lever down to bring the adapters sharply against the faces. Removing the plugs, a standard threading tap is run into the threads to obtain a normal threaded opening. Definite guide marks are cut on this tool so that the threads will not be enlarged beyond the depth specified by the manufacturer in order that, when making up on a new pipe line system, the joint of pipe or nipple will not be run a distance which might conceivably cause undue pressure on the body of the valve and dislocate the wedge and seat setting. If the job of reconditioning the valve has been done correctly, a hydraulic test will show a valve which will not leak, or sweat, in service.

It is obvious that to obtain a high percentage of good valves by reconditioning, a workman above the average must be in charge of this department. It is also obvious that he must be provided with all the tools required to do an effective job, and also he must be given considerable latitude to express his individuality.

Similar valves, which have been cleaned and reconditioned for assembly and test.

Chart for Calculation of Pressure Drop in Gas Lines

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PLOTTED values for pressure difference data permit rapid evaluation of flow factors in given diameter lines and enable calculations to be made without involved computation. Modifications of original Weymouth formula to facilitate plotting permit results from charts within probable error limits of pipe and friction measurements and conforming to standard engineering practice.

CALCULATION of the pressure drop in gas lines enters both into the planning of new designs and the modification of existing systems to utilize their capacity to the fullest extent. The two types of problems commonly encountered in such calculations are those where it is desired to know the pressure difference which must be supplied to give a given quantity of flow and those where the flow which can be obtained with a given pressure difference is to be determined. This article will show how charts can be applied to the solution of such problems.

The Weymouth formula which is commonly used for making such calculations can be written in the form (all pressures in pounds per square inch absolute)

$$p_1^2 - p_2^2 = 87.5 \frac{f l p_1 V_1^2 \rho_1}{d^5} \qquad (1)$$

where
p_1 is the inlet pressure in lb/in.^{2} absolute
p_2 is the discharge pressure in lb./in.^{2} absolute
f is the friction factor
l is the length in feet
V_1 is the volume of flow in ft^3/sec at pressure p_1
d is the diameter of pipe in inches
ρ is the density of fluid in lb/ft^3 at pressure p_1

The disadvantage of using this type of formula is that it involves solution of a quadratic equation for determination of p_2 or p_1 which is necessary if $p_1 - p_2$ is to be found. A further disadvantage of this formula is that it is not readily adaptable to solution by the use of charts.

It can be shown that the pressure drop can be calculated from the equation for flow of liquids for incompressible fluids if a suitable correction factor is applied. The formula for flow of liquids can be written as

$$p_1 - p_2 = 43.75 \frac{f l V_1^2 \rho_1}{d^5} \qquad (2)$$

If the equivalent value of ρ or $\frac{144\, p_1}{RT}$ is substituted in (2) and equation 2 is divided by p_1, we would have

$$\frac{p_1 - p_2}{p_1} = 6300 \frac{f l}{RT} \frac{V_1^2}{d^5} \qquad (3)$$

The value of pressure drop as given by equation (3) will be incorrect. If, however, the approximate value as given by equation (3) is known, the correct value can be determined from Figure 1. The percentage error involved in using equation (3) is shown in Figure 2. The percentage error can be found by dividing the error, which is the difference in equations 1 and 2, by equation 2. Figure 2 can be used to determine the range over which the incompressible flow equation can be applied to compressible flow problems. It is commonly stated that the incompressible flow equation can be applied provided the pressure drop does not exceed 10 percent of the inlet or initial pressure. Figure 2 shows that for this condition, that is $\frac{p_1 - p_2}{p_1} = 0.10$ the percentage of error is 5 percent. The error at any value can be readily determined from Figure 2. The correct value can be determined from Figure 1.

If Weymouth's value for the friction factor $f = \frac{.032}{d^{1/3}}$ is substituted in equation 3, it can be written as

$$\frac{p_1 - p_2}{p_1} = .00513 \frac{L Q_1^2 S}{d^{5\,1/3}} \qquad (4)$$

where
L is the length in miles
S is the specific gravity of the gas
Q is the volume of flow in 1000 ft^3 per day at pressure p_1.

If a length of 1 mile is assumed and a specific gravity of 1 is used, equation 4 would reduce to

$$\frac{p_1 - p_2}{p_1} = .00513 \frac{Q_1^2}{d^{5\,1/3}} \qquad (5)$$

A chart can be easily made for this formula. Such a chart is shown in Figure 3 and 4. Because of the wide range of flow conditions, 2 charts have been drawn. These charts as given will be sufficiently accurate for most calculations and will usually be as accurate as the data. If the friction factor comes within 10 percent of the value assumed the choice will be extremely fortunate. If the diameter varies 2 percent from the nominal values used in making

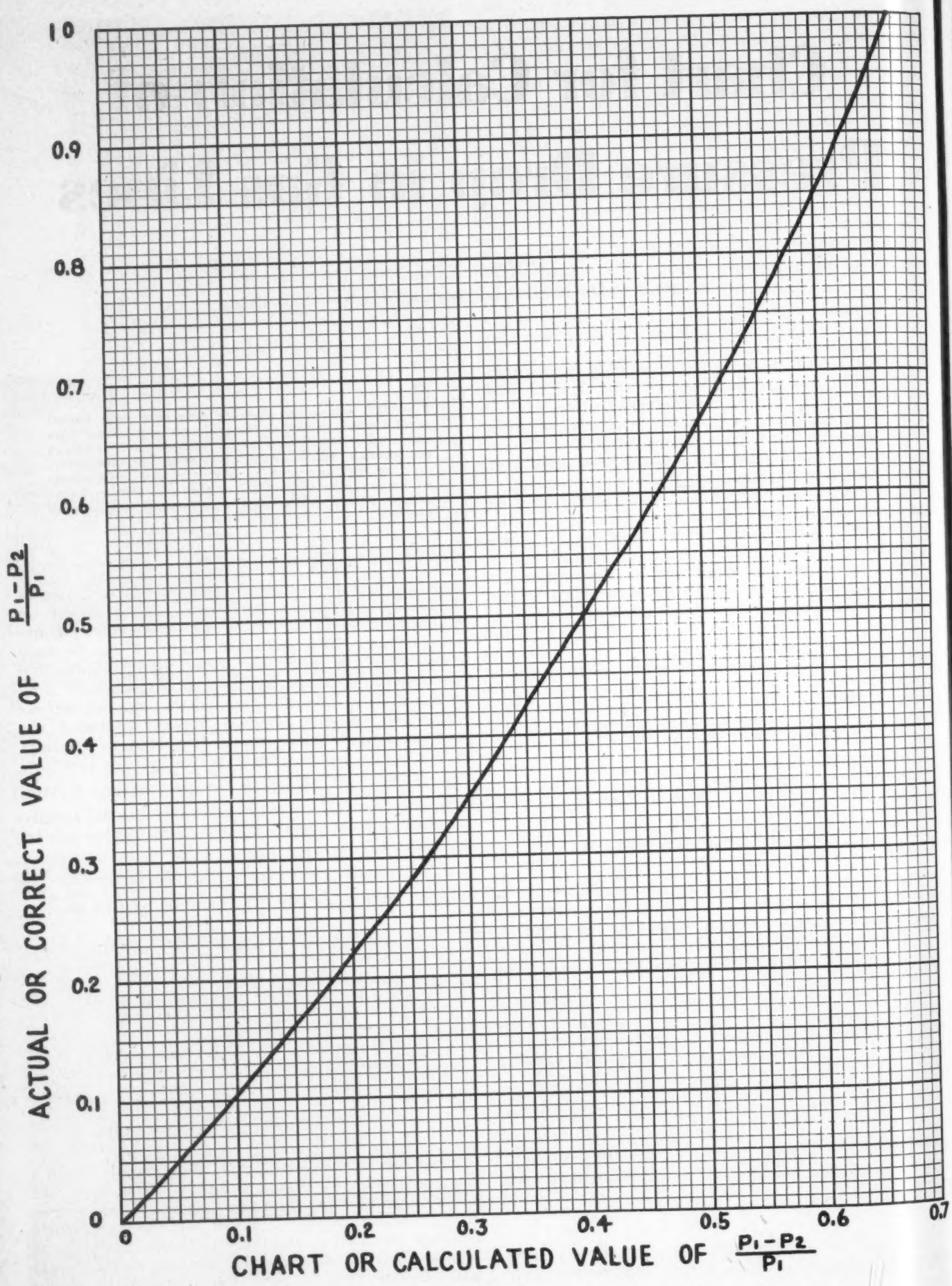
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
ACTUAL OR CORRECT VALUE OF $\frac{P_1-P_2}{P_1}$
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
CHART OR CALCULATED VALUE OF $\frac{P_1-P_2}{P_1}$

FIGURE 1

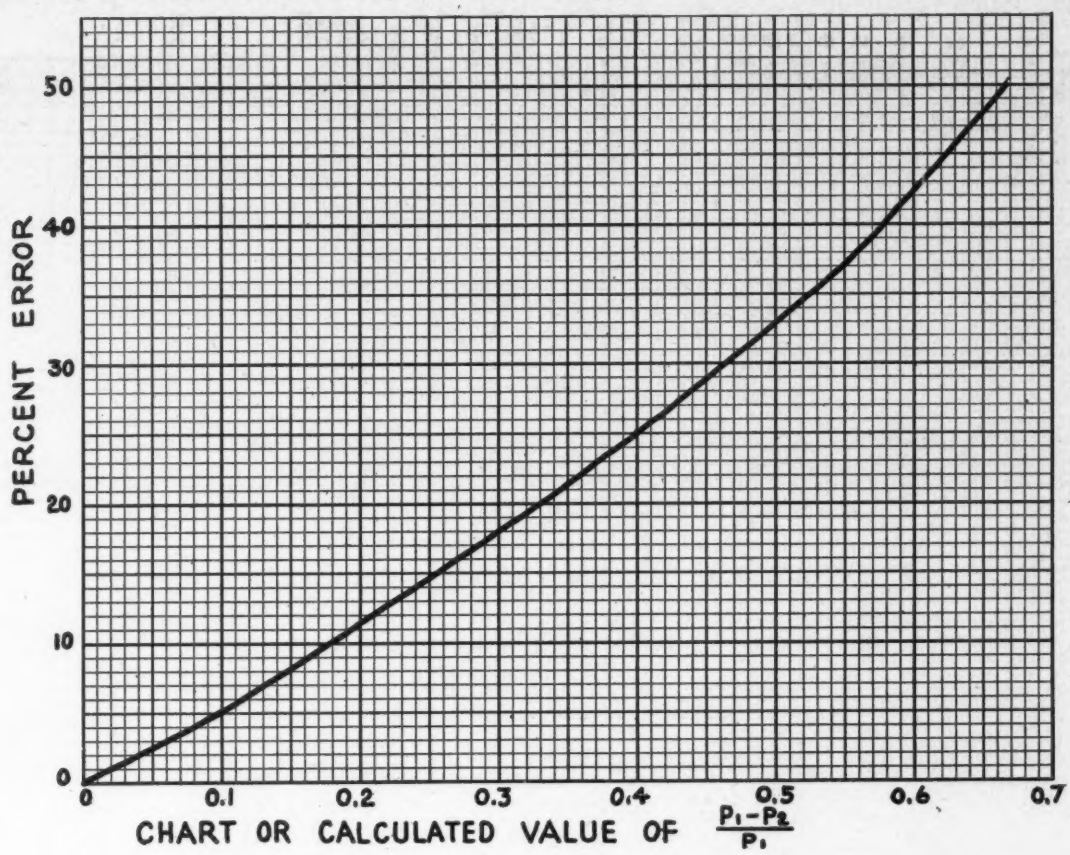

FIGURE 2

calculations it will affect the pressure drop by about 12 percent. When these factors are taken into account the accuracy of the charts will be seen to be as good as required by most engineering problems. If more accurate calculations are desired, the charts can be enlarged and the accuracy will be increased. The accuracy obtained will be equivalent to that from a slide rule having a log scale the length of each cycle on the chart.

In order to facilitate making the calculations Figure 5 has been included. This chart converts the flow at standard conditions to the flow at pressure p_1. The formula for flow of compressible fluids normally includes the absolute temperature. If the specific gravity is measured at 14.7 pounds per square inch and the temperature in the line, no further correction for temperature is necessary. If the correction is not made in the specific gravity it can be made by multiplying the pressure drop by the ratio of absolute temperatures. If T is the temperature in degrees Fahrenheit the pressure drop should be multiplied by $\left(\frac{520}{460 + T}\right)$.

The use of the method outlined above for determining pressure drop is best explained by use of examples. Consider first a case where 340,000 cubic feet of gas per day at 14.7 pounds per square inch are to be handled through a 2½-inch line 20 miles long. The pressure at the inlet of the line is 250 pounds per square inch and the specific gravity of the gas at 14.7 pounds per square inch and the line temperature of 60° F. is 0.7. The problem is to determine the pressure drop in the line and the pressure at the discharge.

The steps to follow are:

1. Find Q_1 at 250 lb/in.^{2}
2. Find $\frac{p_1 - p_2}{p_1 L}$ from chart 3.
3. Find $\frac{p_1 - p_2}{p_1}$ as calculated or from chart.
4. Find correct value of $\frac{p_1 - p_2}{p_1}$.
5. Find $p_1 - p_2$.

Step 1. Find volume $= 340{,}000 \times \frac{14.7}{250} = 20{,}000$ ft^3/day at pressure p_1.

$$Q_1 = \frac{20{,}000}{1000} = 20$$

Q_1 could have been obtained from Figure 5 by entering chart at scale marked gas volume at 14.7 pounds per square inch, at 34,000, tracing across to $p_1 = 250$ pounds per square inch, then down and find $Q_1 = 20$ M cubic feet per day.

Step 2. From Figure 3, find $\frac{p_1 - p_2}{p_1 L}$ by entering chart at scale marked Q_1 = flow in 1000 cubic feet per day at pressure p_1, trace across to line for 2½-inch pipe, then up to line for specific gravity of 0.7, then parallel to diagonal line as indicated and read

$$\frac{p_1 - p_2}{p_1 L} = 0.012 \text{ on upper scale.}$$

Step 3.

$$\frac{p_1 - p_2}{p_1} = L \times \frac{p_1 - p_2}{p_1 L} = .012 \times 20 = .240 = \text{calculated or chart value.}$$

Step 4. Enter Figure 1 on scale reading calculated

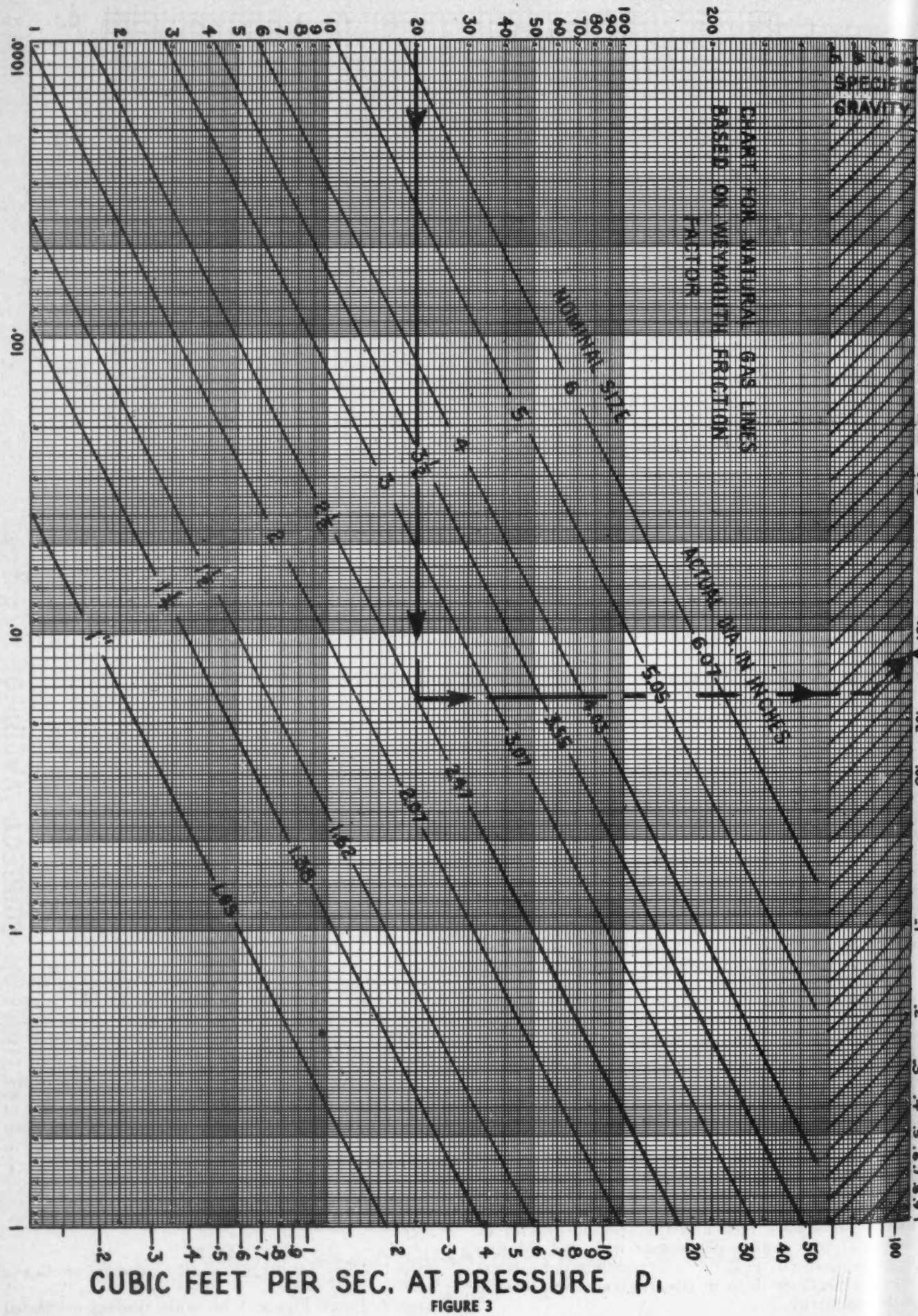
FLOW IN 1,000 CUBIC FT. PER DAY AT PRESSURE P1
CHART FOR NATURAL GAS LINES BASED ON WEYMOUTH FRICTION FACTOR
SPECIFIC GRAVITY
NOMINAL SIZE
ACTUAL DIA. IN INCHES
6.07
5.05
4.43
3.91
3.55
2.47
2.07
1.62
1.38
1.05
CUBIC FEET PER SEC. AT PRESSURE P1

FIGURE 3

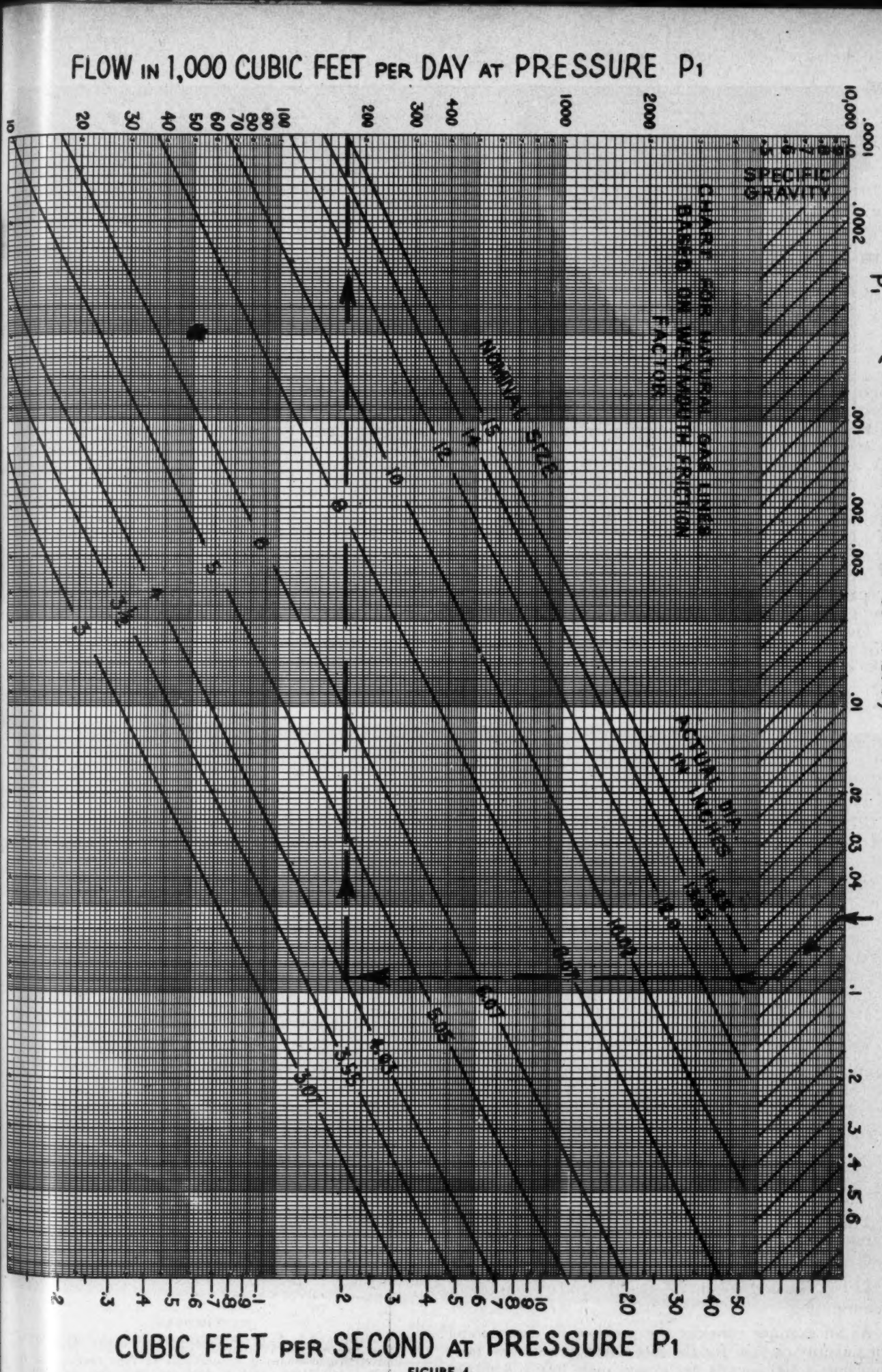
FLOW IN 1,000 CUBIC FEET PER DAY AT PRESSURE P1
CHART FOR NATURAL GAS LINES BASED ON WEYMOUTH FRICTION FACTOR
NOMINAL SIZE
ACTUAL DIA. IN INCHES
SPECIFIC GRAVITY
(P1 - P2)/P1 (CHART OR CALCULATED VALUE)
CUBIC FEET PER SECOND AT PRESSURE P1

FIGURE 4

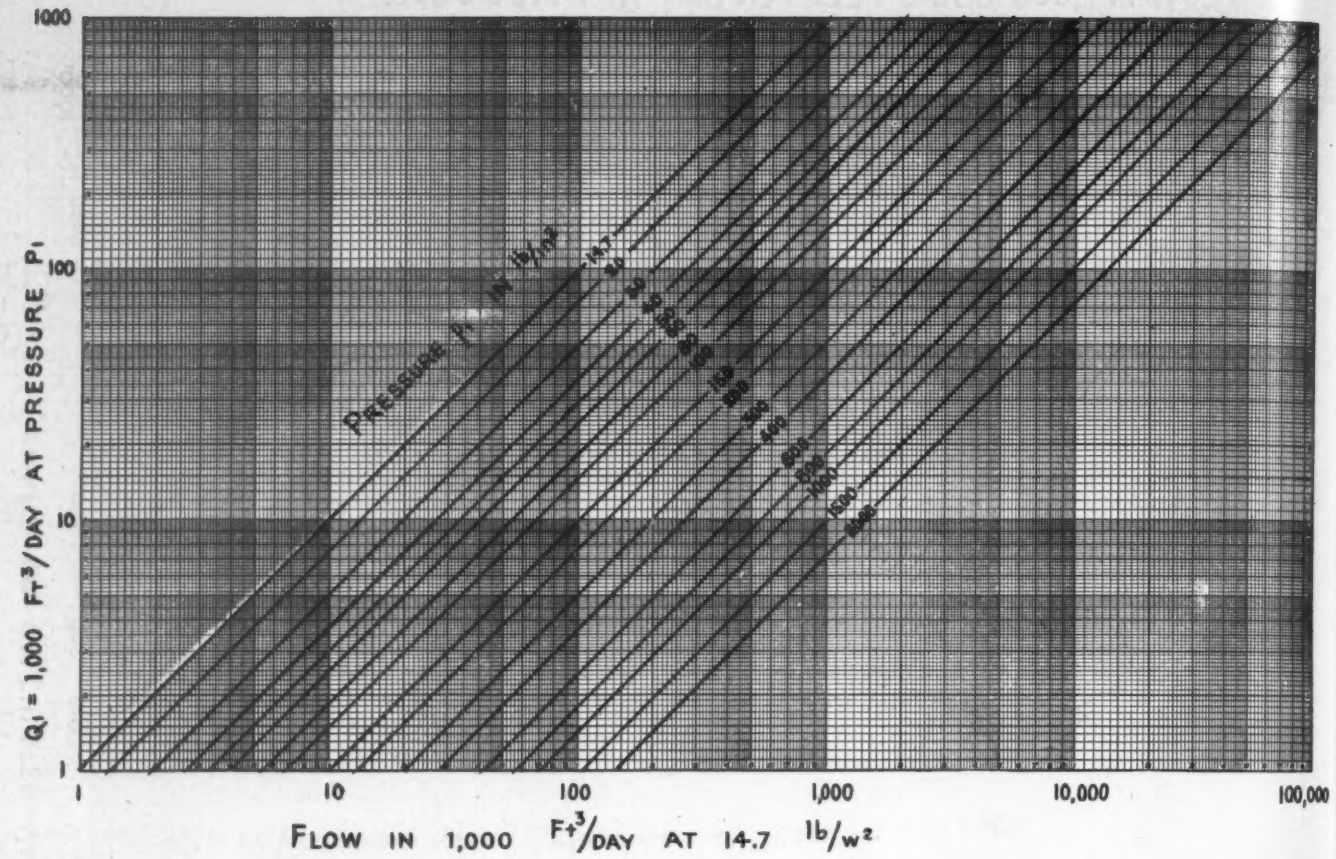

FIGURE 5

or chart value of $\frac{p_1 - p_2}{p_1} = .24$ follow up to curve, then across and read correct value of $\frac{p_1 - p_2}{p_1} = 0.270$.

Step 5.

$$p_1 - p_2 = \frac{p_1 - p_2}{p_1} \times p_1 = 0.270 \times 250 = 67.5 \text{ lb./in.}^2$$

$$p_2 = p_1 - 67.5 = 250 - 67.5 = 182.5 \text{ lb./in.}^2$$

The problem of finding the quantity of flow for a given pipe size is the reverse of this process. The steps are as follows:

Step 1. From pressures find $\frac{p_1 - p_2}{p_1}$ actual.

Step 2. From Figure 1, find $\frac{p_1 - p_2}{p_1}$ from chart or as calculated for formula 3.

Step 3. Calculate $\frac{p_1 - p_2}{p_1 L}$ as based on chart or calculated value.

Step 4. Enter chart (Figure 3 or 4), at top for value of $\frac{p_1 - p_2}{p_1 L}$.

Trace parallel to diagonal lines to value of specific gravity, then trace down to diameter, then across and read Q_1.

Step 5. To find volume of gas at standard conditions use Figure 5.

As an example consider the problem of determining the quantity of flow for the case where pressure at inlet to a line is 400 pounds per square inch, line is 4 inches in diameter and 10 inches long, gas has specific gravity of 0.6 at line temperature, and the discharge pressure is to be 100 pounds per square inch.

Step 1.

$$\frac{p_1 - p_2}{p_1} \text{ "actual"} = \frac{400 - 100}{400} = 0.75 \text{ "actual."}$$

Step 2. Enter Figure 1 at right hand scale reading $\frac{p_1 - p_2}{p_1}$ "actual," trace across to curve, then down and read $\frac{p_1 - p_2}{p_1}$ from chart to be 0.545.

Step 3.

$$\frac{p_1 - p_2}{p_1 L} \text{ from chart} = \frac{0.545}{10} = .0545.$$

Step 4. Enter Figure 4 at value of $\frac{p_1 - p_2}{p_1 L} = .0545$. Trace down parallel to diagonal lines to line for specific gravity equal to 0.6, then down to 4 inch line, then across and read $Q_1 = 175$.

Step 5. From chart 5 or by calculation the volume of gas at 14.7 lb./in.², would be

$$Q = 175 \times 1000 \times \frac{400}{14.7} = 4{,}760{,}000 \text{ ft.}^3\text{/day.}$$

The charts for determining the pressure drop are based on the Weymouth value for friction factor. They will be no more accurate than the value for friction factor and will be applicable over the range of conditions for which the formula has been used by the industry.

REFERENCES

J. A. Hardy and E. N. Kemler—Pressure Drop Calculations for Flow in Pipes—Heating and Ventilating, Aug., 1942, pp. 43-49. E. N. Kemler and N. Kulik—Flow of Natural Gas in Pipe Lines (1942 Spring Meeting of API Pgh). Also in Sept. 24, 1942, Gas Age, pp. 20-26.

Colloidal Fuel Substituded For Fuel Oil

J. F. BARKLEY and L. R. BURDICK
United States Bureau of Mines
and A. B. HERSBERGER
The Atlantic Refining Company

THE shortage of fuel oil caused by the war is forcing oil-burning boiler plants to use coal. The cost of installing coal-burning equipment is frequently quite high. Operators of a number of such plants are giving much consideration to the emergency use in present equipment of mixtures of pulverized coal and fuel oil, popularly termed "colloidal fuel," a substitution that would save about one-third of the oil.

Involved in this decision are questions as to operating problems, the procurement of the fuel and the costs.

To the oil-burning operator, used to the relative ease of handling and burning fuel oil, adding pulverized coal to oil is something of the nature of adding a contaminant. New operating problems, to be solved by properly organized operating routine, arise from the changed characteristics of the fuel. Colloidal fuel is about 10 percent heavier in weight per unit volume than oil; it is about 7 or 8 times as viscous; it requires more power for pumping and pump capacities are decreased; it is much more abrasive; if the coal does not stay in suspension, pastelike accumulations occur in various parts of the equipment such as tanks, heaters, and valves; the ash from the coal in the mixture is set free in the furnace.

To obtain information on the operating problems involved, the Bureau of Mines in cooperation with The Atlantic Refining Company ran about a month's operating test on a colloidal fuel at one of the company's boiler plants at Philadelphia. The test was run as part of the regular plant steam production with the usual company operators. The fuel used was a mixture of 40 percent pulverized bituminous coal and 60 percent No. 6 (Bunker C) fuel oil, no "fixateur" or stabilizer being added.

Previous research at The Atlantic Refining Com-

FIGURE 1

Pulverized coal and oil mixing device showing funnel for coal, mounted on the suction line from tank to pump. Discharge line of pump running toward the left over top of suction line.

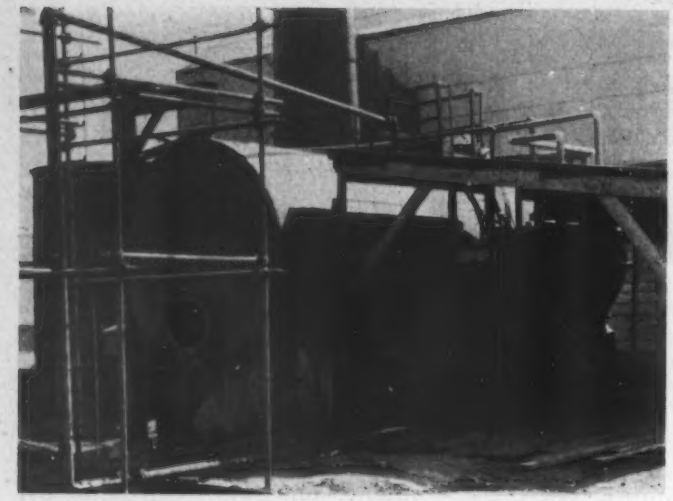

FIGURE 2

Pulverized coal and oil mixing device showing the two horizontal pipes of the discharge line, the two orifices, the vertical pipe and the horizontal pipe to top of tank.

pany's laboratories on stabilities of mixtures showed about 40 percent coal to be the optimum amount. The coals used were high volatile bituminous of about 37 percent volatile and 5 to 8 percent ash with ash softening temperatures ranging from about 2300 to 2700° F. The oil had a viscosity of about 50 to 70 seconds Furol at 122° F. The viscosity of the mixture was about 300 to 500 seconds Furol at this temperature.

Three different batches of fuel were burned, the main differences being in the fineness of the grinding of the coal. Batches of coal were ground to pass about 88 percent, 95 percent, and 99 percent through a United States Standard 230-mesh screen (62 microns), which is considerably finer that that ordinarily used at pulverized coal-burning plants. The laboratory research indicated that the finer grinding would be necessary for a colloidal fuel that would be reasonably stable.

In general, it was found that the mixing of the coal and the oil required for the tests was less difficult than had been anticipated. A simple batch-mixing device shown in Figures 1 and 2 was used. The fuel oil required for the batch, about 7000 gallons, was put in the plant storage tank and then pumped from the tank suction line by an ordinary reciprocating pump. Its temperature was kept at about 85° F. by steam coils in the tank. In the suction line, mounted on a tee and valve, was a funnel kept filled with pulverized coal. The coal under hand-valve control was allowed to flow slowly into the stream of oil on its way to the pump. The mixture was discharged by the pump through two horizontal pipes, each having an orifice near the end as shown in Figure 2.

The two streams of fuel met at the base of the vertical pipe and passed on to the storage tank. The fuel was spilled into the tank at two outlets, one at each end of the tank. The coal was fed into the oil at the rate of about 1500 pounds per hour, the fuel being continually circulated at the rate of about 9000 gallons per hour. After the required amount of coal was fed for the batch, the fuel was circulated for about 12 hours. Laboratory tests of samples of fuel taken at various places throughout the tank showed the mixture to be uniform. No further recirculating of the fuel was done during the burning tests at the boiler plant, the mixing device being valved off from the suction line.

Tests Run on Typical Equipment

The boiler-plant equipment was typical of that of many oil-burning plants. The suction line from the outside oil-storage tank ran underground about 100 feet to the heater-pump set. A steam line, that helped maintain fuel temperatures to the pump, paralleled the oil suction line. Figure 3 shows the heater-pump set. One pump was a reciprocating and the other was a rotary. Figure 4 shows the rotary type. The fuel was heated to about 160 to 180° F. at the set and pumped about 110 feet to the boiler. The burner used was a standard Best steam atomizing burner shown in Figure 5. The fuel reaches a horizontal slot at the burner tip through the lower pipe; the steam reaches a vertical slot through the upper pipe and sweeps the fuel into the furnace. The fuel and steam were under hand control.

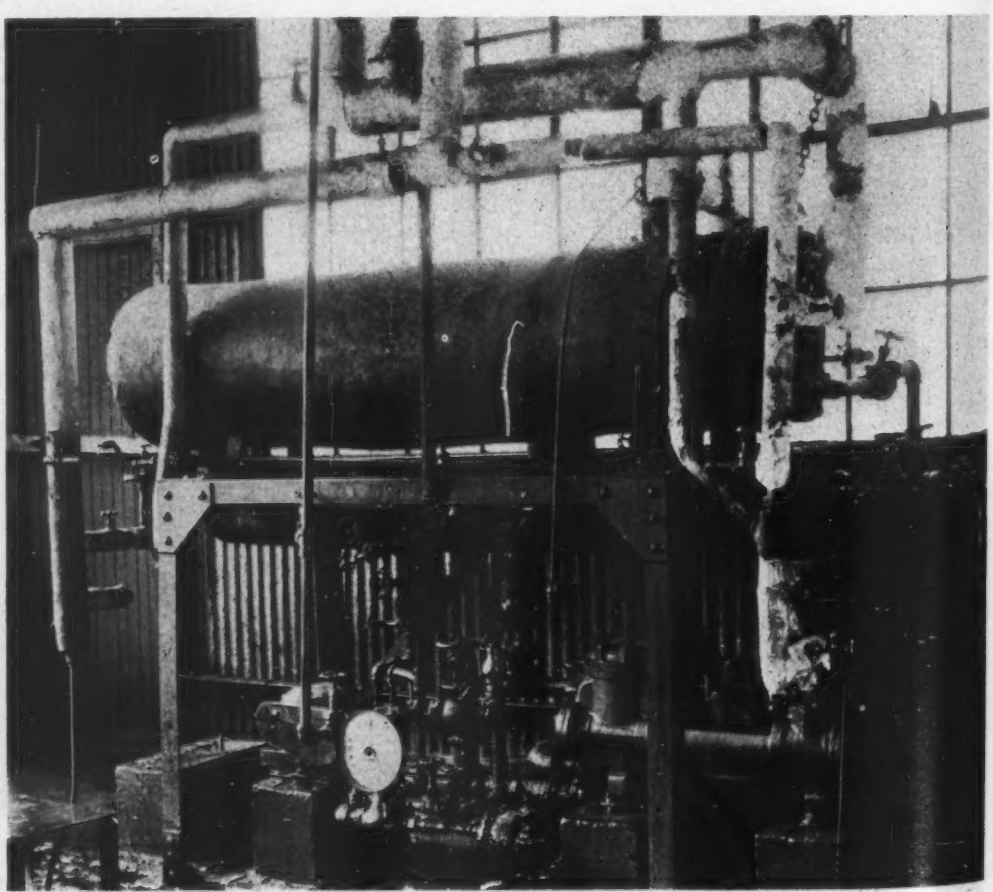

FIGURE 3—Heater pump set used on the tests.

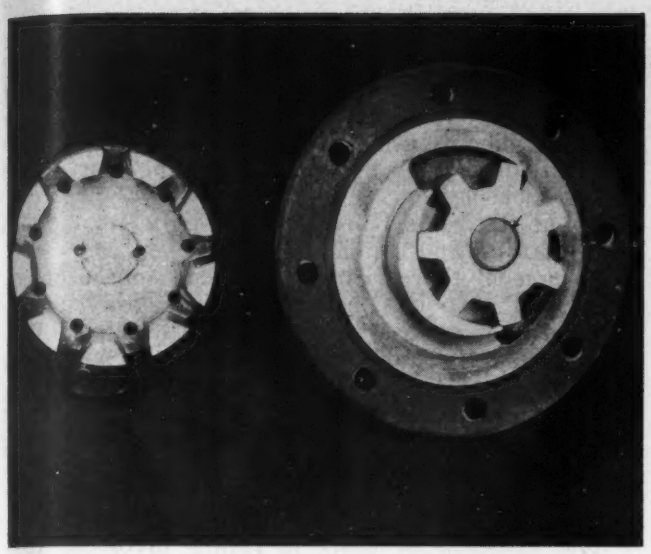

FIGURE 4
Rotary type of oil pump used as part of the heater pump set. Most of the erosion was at the spindle.

Typical Brick Set Furnace

The boiler was a 151-horsepower long-drum straight water-tube B & W, 8 tubes wide and 9 tubes high. Figure 6 shows the boiler front. The furnace was a typical brick-set furnace 10 feet high at the front from the floor to the tubes and 6 feet high at the rear. The furnace width was 5 feet and its length 15 feet, giving about 600 cubic feet furnace volume. The burner entered the furnace at the rear under a horizontal baffle extending about halfway the length of the tubes resting on the first row. The gases crossed through the tubes upward at the front of the boiler, then followed the usual vertical baffling, crossing the tubes twice more to reach the damper outlet at the top of the tubes at the rear.

The boiler was first operated on oil to establish normal operating characteristics. It was then operated continuously on colloidal fuel. Ratings from about 40 percent to over 200 percent were carried without difficulty, but for a considerable part of the test the boiler was operated at about 100 percent rating. At this rating, it was found that the suction at the oil pump dropped from about 1.5 pounds per square inch pressure for oil to 4-inch vacuum for colloidal fuel. The pressure at the oil-control valve was maintained for both fuels at about 30 pounds per square inch. At the burner the pressure for oil was practically zero, for colloidal fuel it was about 2 pounds per square inch. The steam consumption increased about 70 percent. The load on the pump increased. Under one set of operating conditions this load was about doubled. When colloidal fuel is being considered in present plant equipment, thorough attention should be given the problems of increased suctions, pressures and loadings on pumps. Pump capacities may be lowered.

Colloidal fuel has considerable abrasiveness. It acts something like a lapping powder. It is doubtful, however, if this characteristic would necessarily be a serious handicap to successful operation. Equipment affected should be watched and repaired as found necessary. There was wear on the pump shown in Figure 4, most of it at the spindle. No repairing, however, was found necessary during the run. There was also some cutting at the burner tip.

When colloidal fuel is being considered, the question always arises as to the possible settling out of coal from the mixture. This depends on many factors, such as fineness of grinding of the coal, type of oil, temperatures involved and agitation or movement given the fuel. Undoubtedly the finer the coal is ground the better it will remain in suspension. As a practical matter, however, it is desirable not to grind the coal any finer than necessary. Where most settling is apt to occur is in the heater. At this point, parts of the fuel are heated much higher than the average temperature of the fuel leaving the heater; the higher the temperature, the more the settling expected. In general, it is best not to have the fuel any hotter than necessary at any point in the system up to the furnace. Operating routine can be arranged to clean the heater as found necessary. If there are two heaters, they could be used alternately.

On the tests at The Atlantic Refining Company plant, it was found unnecessary to clean the heater on any of the runs that lasted about 7 days each. There was appreciable accumulation, however, in the heater when the 88 percent and the 95 percent coal through 230 mesh were used; there was practically none when the 99 percent coal was used. Some settling in the tank occurred with the 88 percent coal but none with the 95 and 99 percent as long as the storage tank was kept around 85° F. No settling or clogging was experienced in the lines, although they were relatively long. There was some clogging in the meters and screens. Occasionally, throughout the day, the oil-control valve tended to clog, but it could be readily cleared by opening it wide quickly. None of these difficulties were of moment. No boiler shutdowns occurred from operating troubles.

No difficulties arose in burning the fuel in the furnace with the steam-atomizing type of burner. The

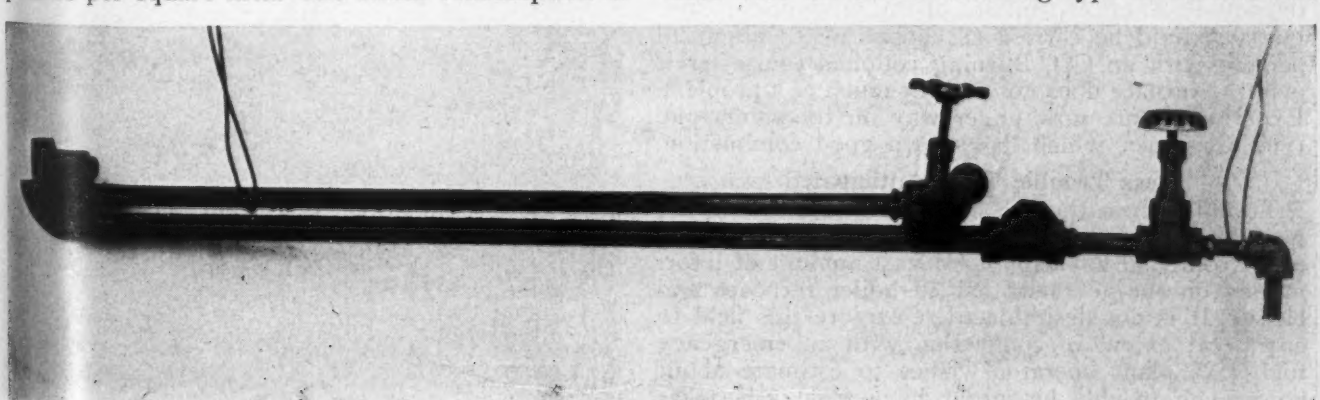

FIGURE 5
Type of steam atomizing burner used. Fuel reaches a horizontal slot at the burner tip through the lower pipe; the steam reaches a vertical slot through the upper pipe and sweeps the fuel into the furnace.

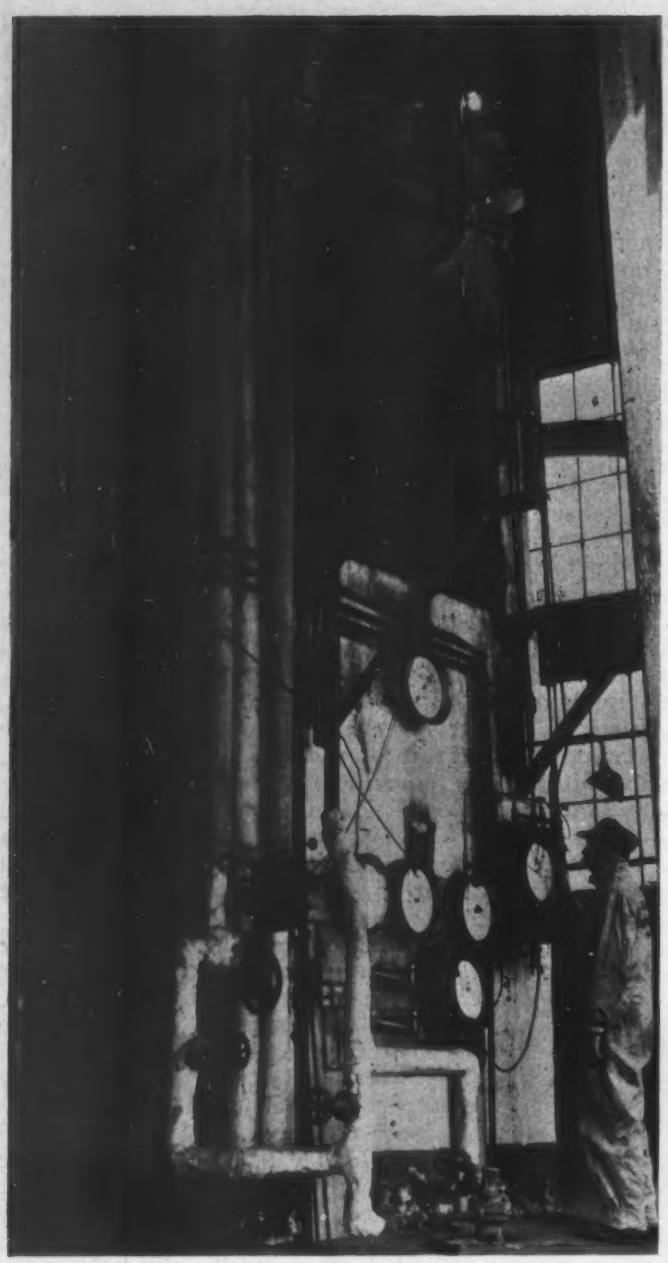

FIGURE 6
Boiler front of the 151 h.p. long drum, straight water tube B. & W. boiler.

flame responded smoothly to changes of boiler load and to variations of the quantity of air used for combustion. It could be controlled with equal ease to fuel oil. The CO_2 content of the products of combustion could be carried as chosen up to about 16 percent with no CO. Burning colloidal fuel after it is in the furnace does not present much of a problem. Experiments are now under way on the rotary-cup type of burner, which has shown good combustion.

Less Trouble Than Anticipated

Troubles from the ash of the coal in the furnace were less than had been anticipated. The use of pulverized coal has supplied a vast amount of information on the action of ash in boiler furnaces and passes. It is not desirable to re-explore this field to any great extent in connection with an emergency fuel. If a plant operator wishes to estimate about how much trouble he might have from ash, what those troubles are, and how they can be met, he might visit a few pulverized-coal-burning plants that are similar to his plant and operating with similar coal at about the same loads. In general he should expect much less ash troubles. Figure 7 is a view of the furnace with the ash accumulation after about one week's operation. There was no dripping or slagging. The fly ash on the tubes was cleaned without difficulty every 8 hours during the test by the boiler soot blowers.

About the same boiler efficiencies were obtained with both oil and colloidal fuel.

At present there is no commercial source of colloidal fuel. Various concerns are considering its production. Larger users could consider setting up their own grinding and mixing plants. This is now being done by at least one oil user. Studies are now being undertaken by the Bureau of Mines and The Atlantic Refining Company to arrive at a low cost mixing device. There is now on the market standard pulverizing equipment that will grind coal to the fineness of that used on the tests.

The question of costs is rather involved. How much can be afforded for the emergency fuel is an individual matter. The cost of equipment for complete conversion to coal may be very high. Under normal conditions in the past, the use of colloidal fuel has never proved itself to be an attractive proposition. Most oil-burning plants are in areas where under under normal conditions it has been economical to burn oil. Colloidal fuel will cost more if the cost of handling, pulverizing, and mixing of the coal results in a coal B.t.u. cost higher than the oil B.t.u. cost. If needed equipment is obtainable, The Atlantic Refining Company estimates that, on a production scale of 1,000,000 barrels of colloidal fuel per year, this fuel could be sold in their area at about the same cost per million B.t.u.'s as that of the 16-gravity fuel oil now being delivered.

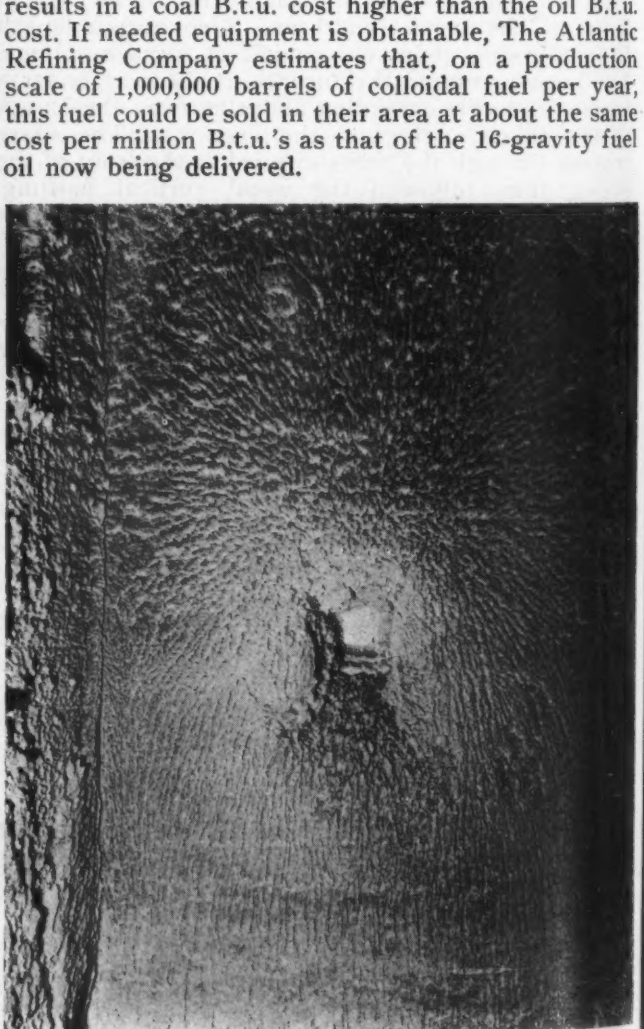

FIGURE 7
Interior of boiler furnace showing ash accumulation after about a week's operation.

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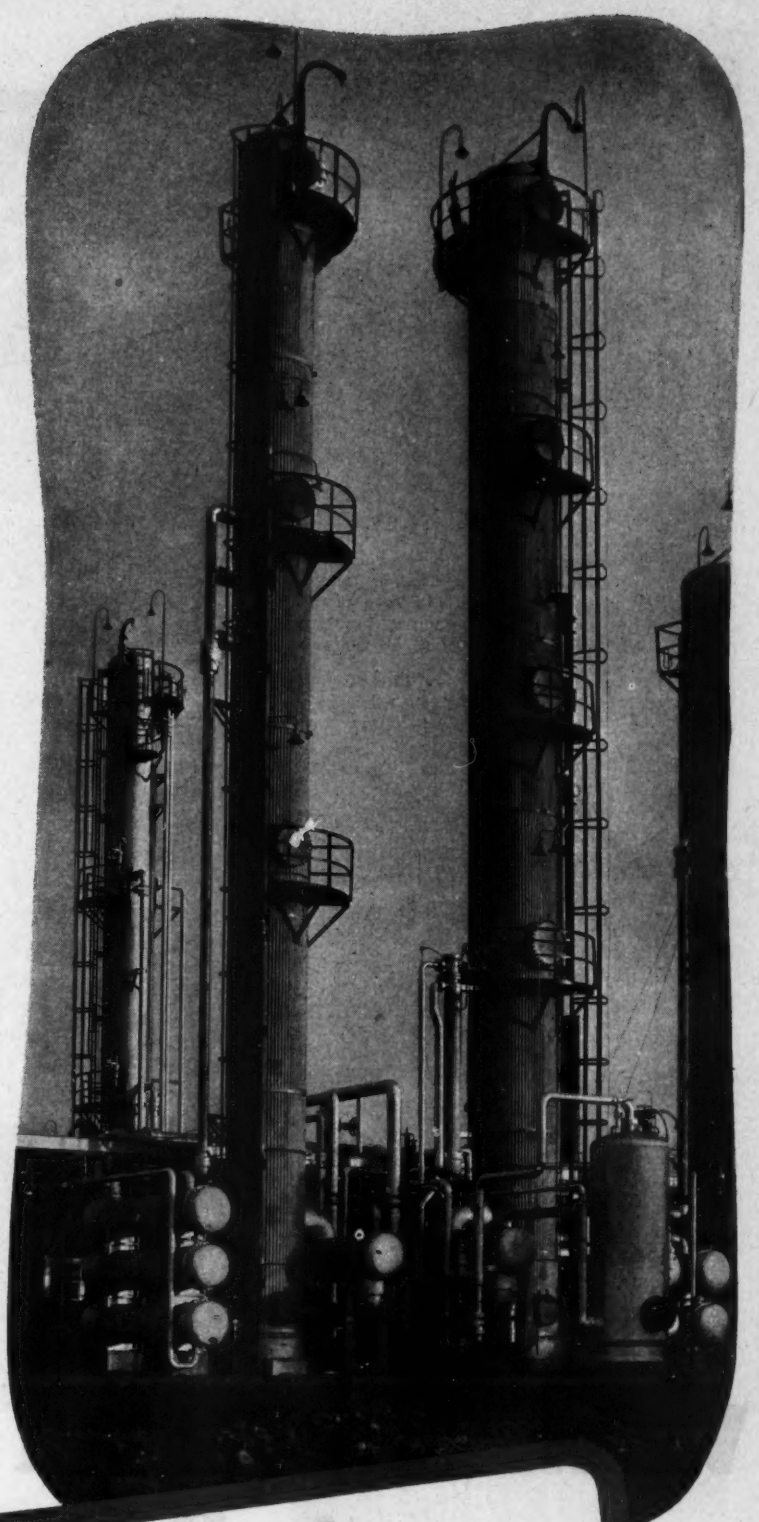

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Alcia Ricketts has a husband in the service and a job helping Uncle Sam in the war. She is one of several women who have replaced men as tank gaugers for Standard Oil Company of California.

Women Efficient at Many Jobs Formerly Reserved to Men

NOT the least significant of the changes brought about by the war is the important place being taken by women in doing jobs formerly held only by men. So rapidly are women being absorbed into all types of industrial work that the whole labor picture is being colored by their participation in it.

Figures emphasize the extensiveness of the change now in progress. For example, in December, 1940, the total number of women in United States industry, excluding any agricultural pursuits, was 10.2 million. By April, this year, the total stood at 14.1 millions, or an increased employment of women during little more than two years, of 4.1 million. About 1.7 million of these began work between April, 1942, and April, 1943. The total is due to grow perhaps a million more during the rest of this year.

Such numbers of women getting into industrial work for the first time is a phenomenon to say the least and implies widespread adaptation on their part, and surely a revolution in one sense of the word in the industries where they are being absorbed. But results have been highly encouraging in

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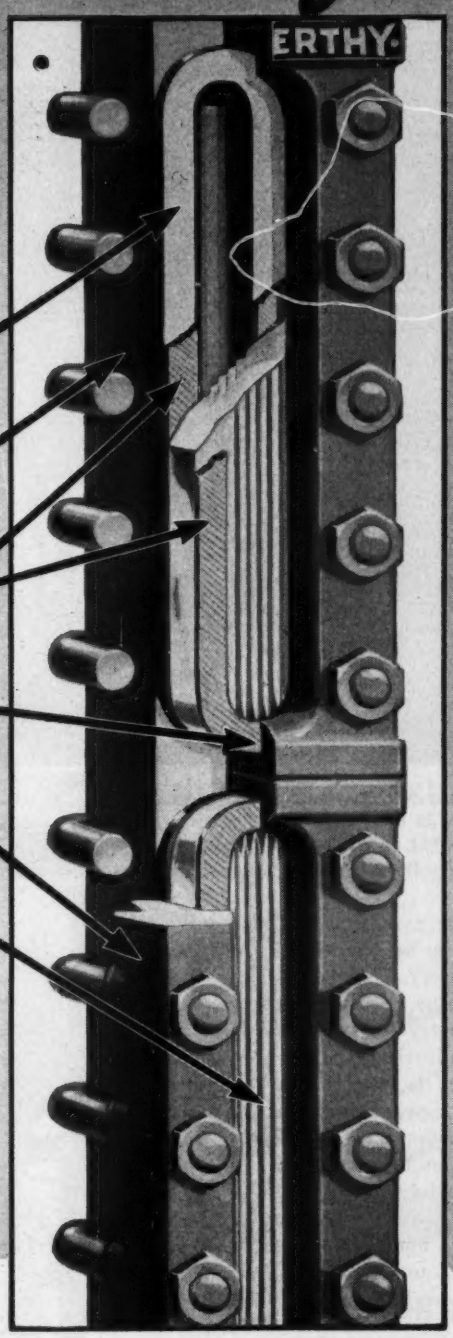

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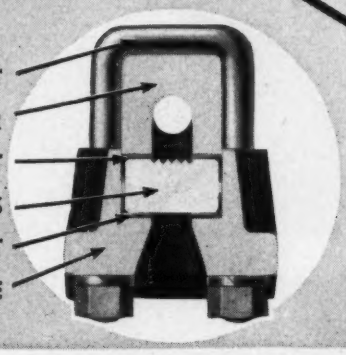

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Her husband is a Marine Corps lieutenant on active duty in the Pacific. She, too, is helping to win the war by analyzing hydrocarbons in a research laboratory.

the whole experiment. Universally, the situation is satisfactory to both women and industry.

The same reluctance to take women into industry generally has prevailed in the oil industry, and still does to a great degree. It is true that at first thought the two appear somewhat incompatible. There seems at first glance to be little that women can do outside oil company offices to have any affect on the manpower shortage. However, a few companies are finding this idea false. Standard Oil Company of California, for example, now has women working in the fields.

"Several months ago the company's producing department employed its first women pumpers in the oil fields. Twice during her 8-hour shift the pumper visits each oil well in her string, anywhere from 40 to 70 wells, to see that the engines are properly lubricated and the wells are producing correctly. She gauges the oil from the wells and draws off any water that may have settled to the bottom of the tanks." So writes Edgar A. Waite, manager of the Public Relations Department of Standard Oil Company of California.

Early last year at the mere suggestion that women be considered to replace men in field jobs, experienced supervisors shook their heads. Today these same skeptics are inclined to brag just a little about the "girls," a good many of whom are grandmothers. "They're doing okay!" is the general verdict.

"A survey of the company disclosed that women could be hired for most work that did not require special technical skill, long years of training, or lifting beyond the legal limits of 25 pounds," Waite explained. "It was found in many cases that by careful juggling, technical or heavy portions of jobs could be combined and assigned to experienced men, leaving the lighter, routine parts to women."

The natural-gasoline department was the first division of the company to hire women for outside work in the fields. Already 10 percent of the workers in this department are women, and it is predicted that eventually the figure will grow to 20 percent. Women have replaced men roustabouts and gasmen helpers in the field and in laboratories. They test samples, run distillations on natural gas, change charts, "walk" gas lines and check lines to see that the flow

She is not quite five feet tall and can fire a still as well as any man.

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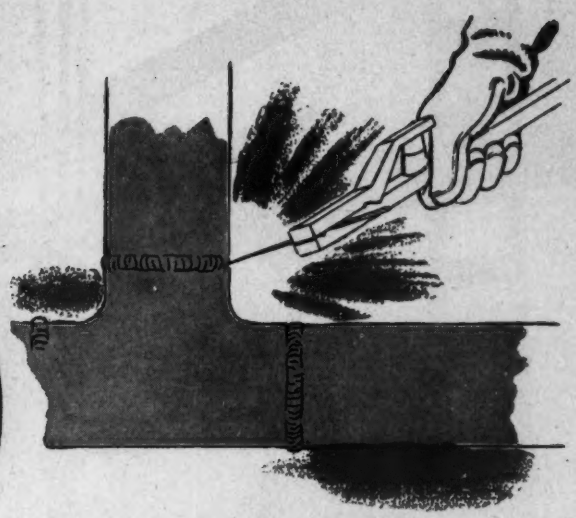

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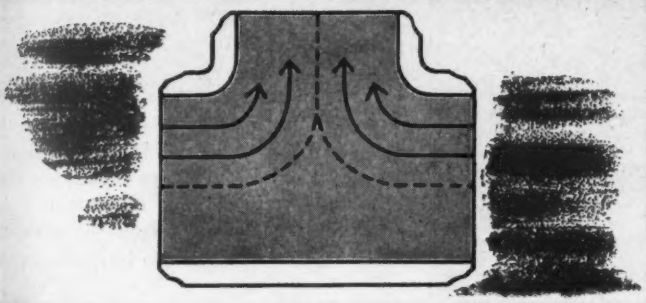

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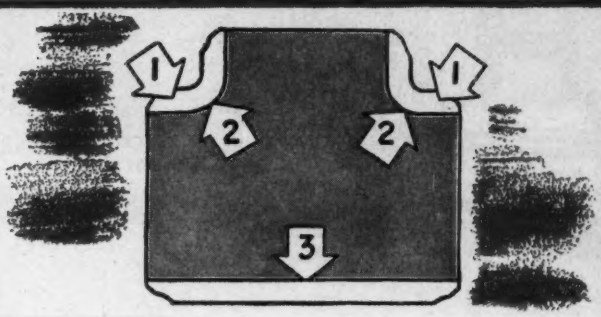

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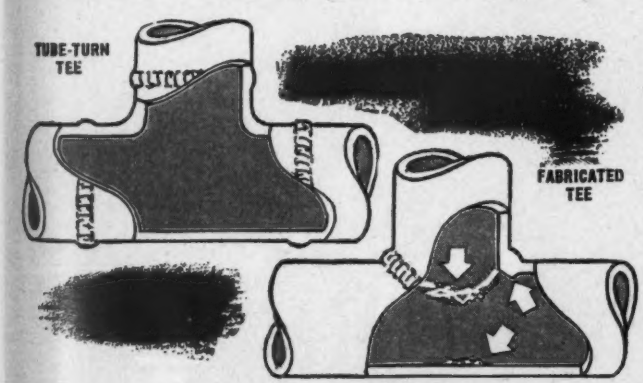

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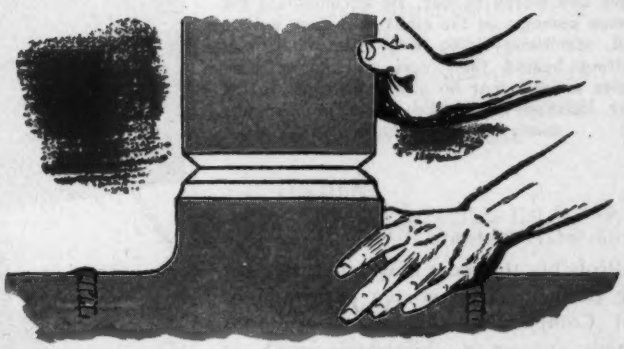


FASTER, EASIER ALIGNING

Accurate bevels, plus I.D. and O.D. that exactly match the pipe, make aligning simple and speedy.

TUBE-TURN
Welding Fittings and Flanges
NO. 8 OF A SERIES
HOW TUBE-TURN WELDING FITTINGS BENEFIT WAR INDUSTRY
The FIRST WELDING FITTINGS 1ST AND STILL THE BEST

Emily Lunch, pumper in a Standard Oil Company of California lease, field, with "Pooch," the busiest dog in the oil business . . . A stray who wandered into the oil field and promptly nominated himself official bodyguard for women replacing men pumpers, "Pooch" works by night and sleeps by day. He accompanies the women pumpers on the night shift from well to well, sometimes riding with them, sometimes trotting behind their cars. He knows their routes so well that he often starts off to the next location in advance of a pumper and meets her when she arrives.

of gas is not restricted by the accumulation of condensate.

Probably the most unusual service being performed by women for Standard Oil Company of California are jobs which are on a shift basis such as booster-plant and extraction-plant-operator helpers. These women act as engine-room attendants in some of the larger plants.

On a hill near a refinery one woman takes care of a number of tanks which receive crude oil from pipe lines. She climbs the tanks every hour, gauging and taking samples. In her hands rests the entire responsibility of controlling flow from these tanks to the refinery stills.

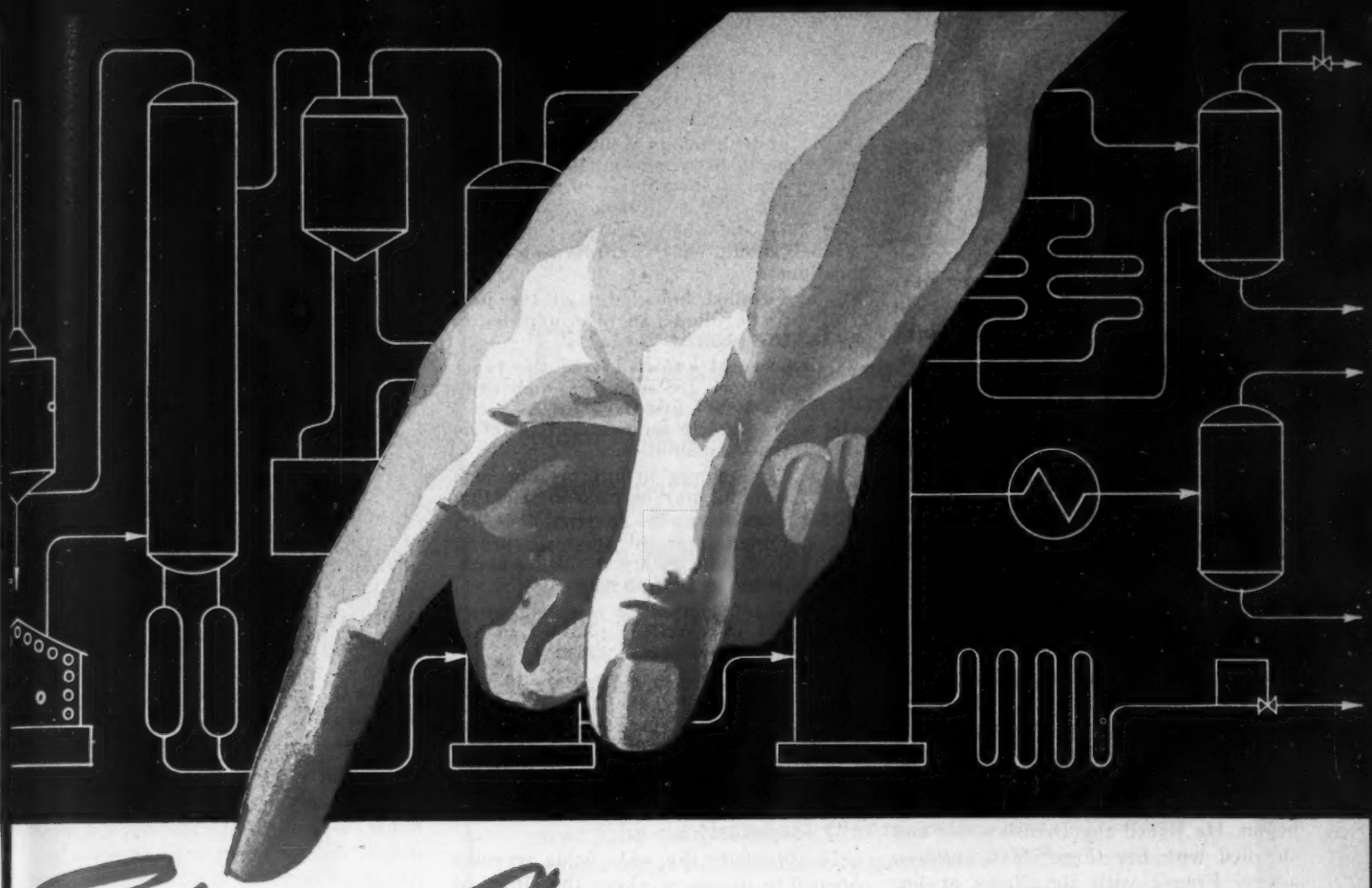
Some women have found that dogs make good companions on the job. A stray attached himself to the pumping crew of a string of wells in the Taft area, riding with each woman pumper as she made the rounds. The dog works 24 hours a day 7 days a week, accompanying all shifts on this string.

Continental Oil Company is using women to replace men in seismograph crews, as assistant computers. The women computers travel with the crews and work in temporary field offices. Their duties include the labeling and cataloguing of data incidental to calculations of structures from the seismograph records.

Facing the problem of manpower shortage, the United States Department of Labor recognizes the call being placed on women, and further large additions of women workers are predicted for the rest of this year. The department points out that women can give their best service only if they are placed in jobs for which they are best suited and recommends definite procedure in employing women.

The first step in a sound placement program for women is selecting, on the basis of job analysis, the job suitable for them. These analyses reveal not only the skills required but the physical demands of tasks in terms of strength, posture, and exposure to hazards. In the

Feminine barrelhouse worker starting an empty barrel down the conveyor.



Short Cut TO POST-WAR PROFITS

WHAT the fuel and lubrication requirements of tomorrow will be cannot yet be accurately foretold. The refiner who can quickly and economically meet those requirements will be in a profitable position after the war.

McKee engineering takes advantage of all the short cuts in modern petro-chemistry to eliminate or combine process steps. Flexibility of operation, a built-in feature of McKee refineries, enables you to switch quickly and inexpensively from one operation to another.

These features of McKee design assure you *economical operation* by employing a minimum of processing steps and *flexible operation* necessary for quick conversion to post-war operation.

The McKee organization is at present engaged in engineering and construction of plants for many of the following products and processes:

TOLUENE
PETROLEUM SYNTHETICS
BUTADIENE
CATALYTIC CRACKING
ALKYLATION
GAS CONCENTRATION
ISOMERIZATION
HYDROGENATION
DEHYDROGENATION

McKee's highly specialized services are available to you on any type of refinery project.

Arthur G. McKee & Company

★ *Engineers and Contractors* ★

2300 CHESTER AVENUE • CLEVELAND, OHIO

30 ROCKEFELLER PLAZA, NEW YORK, N. Y.

COMMERCE BUILDING, HOUSTON, TEXAS

process of such analysis, engineering changes may be indicated that will lessen the physical demands of the job and at the same time increase operating efficiency.

Hand in hand with the importance of selecting jobs suitable for women goes the importance of selecting the right woman for the particular job. Matching the women to the job is the real problem with which industry must concern itself.

With Standard Oil Company of California, it was found that more attention from a personnel standpoint has to be given to women than to men. The task of selecting women for war jobs was turned over to Mrs. Virginia Harrison who not only handles the hiring of women, but also acts as their friend and counselor.

Mrs. Harrison's background has given her a deep and real understanding that the war is a matter of life and death, and not just something to read about in the headlines. She and her husbnd were living in Paris when hostilities began. He joined the British army and she fled with her three small children across France with the Nazis at her heels. When she arrived back home in this country, she immediately sought a war job and was employed by Standard Oil Company of California.

The hiring of women for work in the refinery was a problem in the beginning. First, Mrs. Harrison had to find out for herself just what each type of job required of the worker. Then she helped devise a simple aptitude test to determine if women applicants were mechanically inclined. Several training periods were established for accepted applicants, in which they work under supervision before becoming full-fledged operators.

According to the Department of Labor's findings, such a detail as a carefully drawn application blank goes far in simplifying the selection procedure for women.

For successful selection of women for war-industry jobs, the Women's Bureau of the department recommends:

1. Prior to selecting women for the jobs, a careful analysis of the plant should be made to determine:
   a. Which jobs are suitable for women.
   b. Which jobs can be made suitable for women.
   c. What changes are necessary in conditions surrounding the job, as for example in height of seats or benches, in weight of machine parts or of products to be handled, in installation of mechanical lifts, and so forth.

2. The Persons who are to select women should have the following qualifications:
   a. Detailed knowledge of the jobs to be filled and of conditions in the plant.
   b. General knowledge of the types of work for which women ordinarily are fitted.
   c. Interest in women and belief in their capabilities.
   d. Competence in interpreting such tests as may be used in selecting women.
   e. Freedom from personal prejudices, and ability to inspire confidence in the job seeker.

3. The procedures for selecting women should be carefully planned in advance and, may well include:
   a. Provision of simple and adequate application blanks.
   b. A series of interviews, with purposes of securing information, giving information, and establishing friendly relations.
   c. Tests rigidly tailored to fit the specific job.

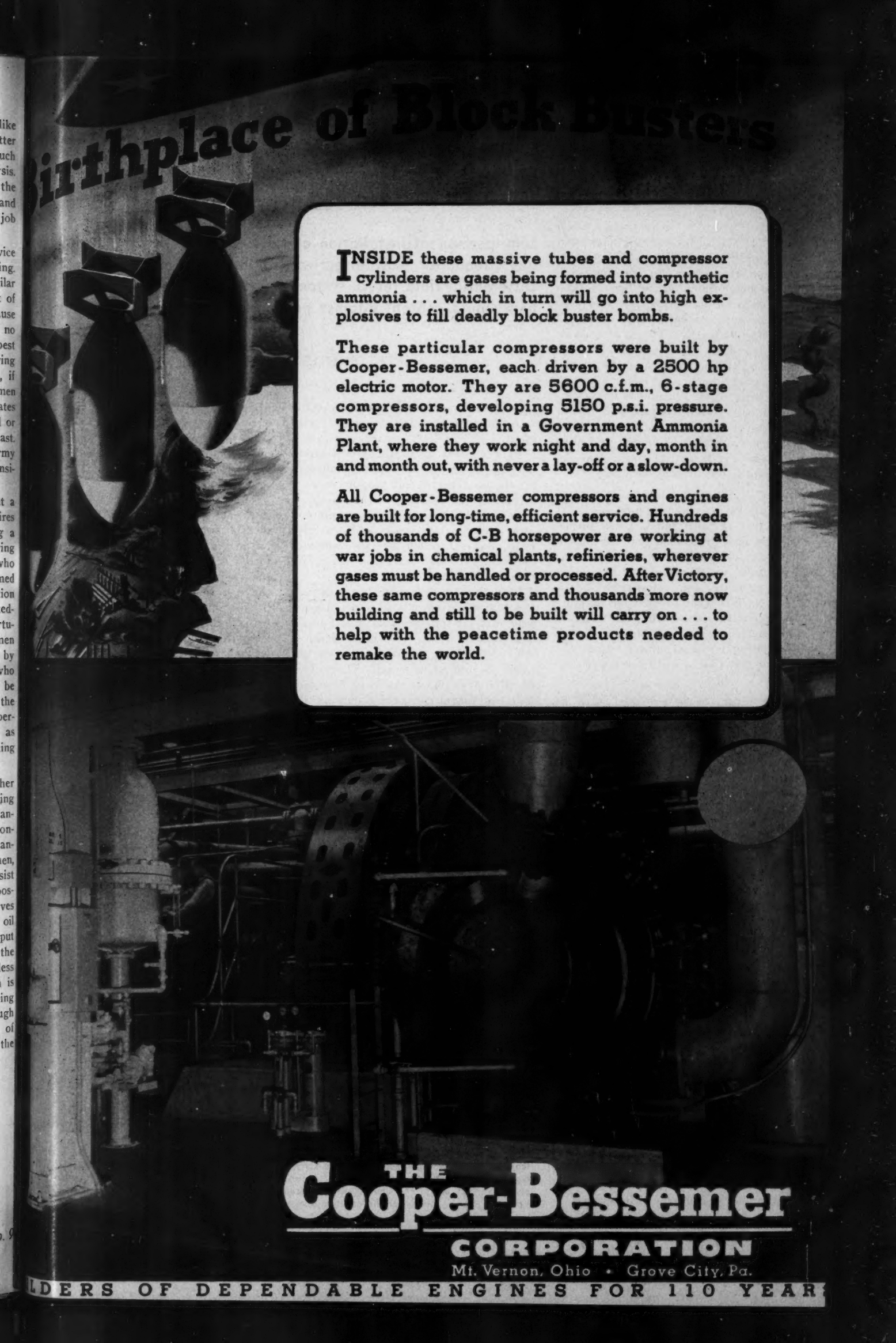
In surveying the wide fields recently opened to women workers, the Office of War Information has been able to make deductions that apply pretty generally, and support the rapidly growing belief that women are in industry to stay. The OWI study brings out that changes manufacturers have had to make to accommodate women are for the good of men as well in a majority of instances. Also changes are less drastic generally than first considered. Psychological adjustments made by both employer, worker and public usually have outweighed in importance the mechanical changes and job simplifications that have had to be made. The distinction between "man's" work and "woman's" work is rapidly fading. Simplification of jobs by breaking them down has increased production. Jobs have been made more attractive. New fields have been opened to women, notably the widespread assignment to women as counselors and personnel officials, a field formerly entirely closed to women.

It probably is not possible to make up the shortage of manpower in the oil industry by using women workers, since the acute shortage affects technically, or specially trained personnel. However, as has been realized in other industries, there is perhaps room for some juggling and shifting, combining, or like adjustments that might result in better use of manpower available. Too much stress cannot be placed on job analysis. It is the foundation stone in getting the most from personnel available, and should be the key point in every job problem.

Recently there has been sound advice given the industry on geology thinking. It is altogether possible that similar advice is needed in the employment of help. Prejudice against a thing because it has never been done is, after all, no real argument. The Army is the best example to be found of facts disproving prejudice. A very short while ago, if anyone had even mentioned that women would be a part of the United States Army, he would have been ridiculed or considered a dreamer to say the least. And yet, women are a part of the Army —with the same privileges and responsibilities as men.

Some oil field work is rough, but a good deal is not. Much of it requires no more endurance than managing a house, looking after children, preparing meals, duties which most women who live in or near the fields are accustomed to year in and year out. A re-valuation of jobs by companies would undoubtedly reveal that there are many opportunities for substitutions whereby women could be given work usually done by men. In all probability women who could qualify for such jobs would be more than glad to take them, for the duration of the war only, thereby performing a patriotic service as well as carrying on while the man is fighting or serving the country otherwise.

The theory is working in all other types of war plants, with ever widening scope of activity by women. War Manpower Commission is apparently convinced that the solution to the manpower shortage lies in the use of women, and is exerting all its influence to assist in training programs and all steps possible to aid women prepare themselves for such work. Peculiarities of the oil industry, particularly producing, put certain limitations on personnel, but the same thing is true to a greater or less degree in all industries. Adaptation is the job to be done. It is a case of going around the wall if we cannot go through it, and a more comprehensive use of women in the oil industry may be the way round.



INSIDE these massive tubes and compressor cylinders are gases being formed into synthetic ammonia . . . which in turn will go into high explosives to fill deadly block buster bombs.

These particular compressors were built by Cooper-Bessemer, each driven by a 2500 hp electric motor. They are 5600 c.f.m., 6-stage compressors, developing 5150 p.s.i. pressure. They are installed in a Government Ammonia Plant, where they work night and day, month in and month out, with never a lay-off or a slow-down.

All Cooper-Bessemer compressors and engines are built for long-time, efficient service. Hundreds of thousands of C-B horsepower are working at war jobs in chemical plants, refineries, wherever gases must be handled or processed. After Victory, these same compressors and thousands more now building and still to be built will carry on . . . to help with the peacetime products needed to remake the world.

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Cooper-Bessemer
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Mt. Vernon, Ohio • Grove City, Pa.

LDERS OF DEPENDABLE ENGINES FOR 110 YEAR

Distillate Well Production Problems Studied With Testing Equipment

Semi-permanent installation at Katy field well testing two-phase gas stream for most effective sampling and metering methods. Differential fluid return system permits test runs on variable and high liquid content against previously calibrated determinations

ELTON STERRETT, Staff Writer

EQUIPMENT is now moved in and connected for the start of the latest unit in the series of distillate-well studies inaugurated by the Natural Gasoline Association of America something over a year ago with tests on a well near Corpus Christi. The new series of tests, based on experience and findings from the earlier runs, involves a complete revamping of test equipment, and the setting of all equipment on a basis which will permit continuation of the work over an extended period, with possible tying-in of equipment or units for later check against basic data derived from the present series.

Well No. 9 of the Katy unit, located west of the new plant at that field, has been tied in with block gates on its regular flow system so that the output may be diverted to the test set-up. Apparatus at this point will provide well pressure and temperature data. The test line leads to the high-pressure test separator, at which point it again branches, it being possible to send all flow through the separator, or to bypass it and flow directly to the second unit.

The separator is equipped with an adjacent fluid storage chamber, in which the efflux from the separator may be run, and from which it may later be picked up, by establishing pressure differential, and added to the gas stream from the separator so as to provide any desired liquid content.

Beyond the junction of separator discharge line and the bypass is a vertical loop in which the hairpin member may be either of 4- or 2-inch pipe, as desired. A vertical lubricating fitting is provided at the first tangent of the loop to permit inserting of the desired sampling tubes. On the downflow side of the loop provision is made for metering in a vertical line, while a short distance farther along, on the run, horizontal metering may be established, and direct comparison of the two methods obtained.

A second separator, with a discharge pressure of 1250 pounds is so tied in with the layout as to insure that all gas passes through this unit, regardless of whether it has previously been processed by the first unit or not. Flow from this separator goes through lines tied in with the usual well system so that neither gas nor distillate obtained by the test procedure will be wasted.

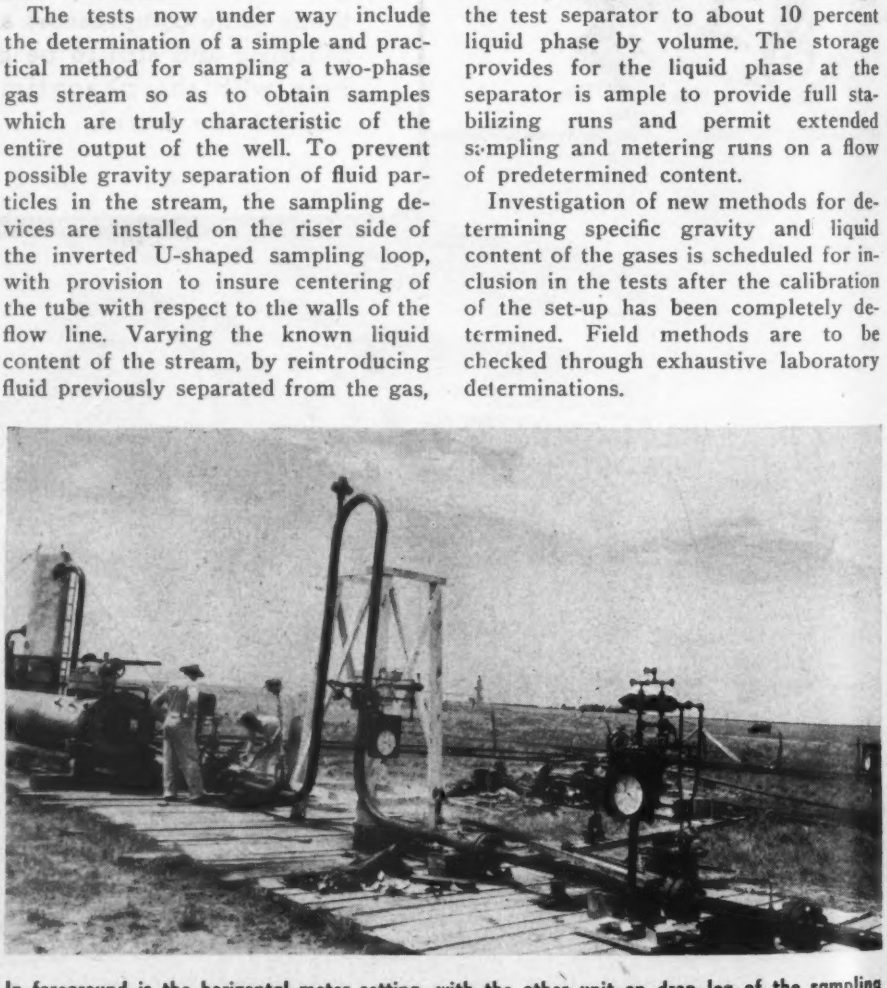
Adjustable chokes provide varying rates of flow through the test equipment, with orifice meters on each branch so that accurate determination may be made not only of the full well production, but of that proportion of it diverted to any portion of the set-up.

Calibration tests of the equipment were initiated last week, with the full-flow runs scheduled for the week of September 6 and thereafter as equipment is available.

The tests now under way include the determination of a simple and practical method for sampling a two-phase gas stream so as to obtain samples which are truly characteristic of the entire output of the well. To prevent possible gravity separation of fluid particles in the stream, the sampling devices are installed on the riser side of the inverted U-shaped sampling loop, with provision to insure centering of the tube with respect to the walls of the flow line. Varying the known liquid content of the stream, by reintroducing fluid previously separated from the gas, will make it possible to determine the effective operating limits of different types of sampling devices, and to set up comparative data from which their results may be calibrated and converted.

The pressure range at the new set-up is variable from a low of 1000 to a high of 2500 pounds per square inch or field producing top. Fluid range in the gas tested will grade upward from that of the stripped gas after its pass through the test separator to about 10 percent liquid phase by volume. The storage provides for the liquid phase at the separator is ample to provide full stabilizing runs and permit extended sampling and metering runs on a flow of predetermined content.

Investigation of new methods for determining specific gravity and liquid content of the gases is scheduled for inclusion in the tests after the calibration of the set-up has been completely determined. Field methods are to be checked through exhaustive laboratory determinations.



In foreground is the horizontal meter setting, with the other unit on drop leg of the sampling loop. At left is storage vessel for liquid stripped from the gas by the first or test separator. The type of equipment and semi-permanent nature of the installation are apparent in the mounting of the various units. The line is welded except where design features include the possibility of revision or the addition of new equipment as the tests progress.

Jeffers Resigns as Rubber Director; Dewey Succeeds to Post

William M. Jeffers resigned September 4 as Rubber Director. His return to the presidency of the Union Pacific Railroad means that he is confident the synthetic rubber program will meet the requirements of the report of the Baruch Committee.

The President named Bradley Dewey to succeed Jeffers. Dewey has been named Deputy Director and Jeffers recommended the promotion. His promotion means that those familiar with developments are convinced that operation of plants rather than their construction is now paramount. Dewey, head of the Boston chemical firm of Dewey & Almy, has been connected with the program since Jeffers became director. In cooperation with technologists of Rubber Reserve Company, the petroleum industry, the chemical industry and the rubber industry, he has supervised process development, especially in the copolymerization of synthetic rubber.

Jeffers' letter to the President gave this estimate of plant status:

"All of the major synthetic-rubber plants, the construction of which is under the jurisdiction of the office of rubber director, are either completed or substantially so with the exception of three. Practically all of the material is available for the completion of these three plants but inasmuch as they are dependent upon feed stocks from aviation gasoline plants, there is no need for crowding their completion in advance of the availability of these feed stocks."

Jeffers was called to Washington shortly after the committee headed by Bernard M. Baruch had outlined requirements for solving the rubber shortage. He accepted the recommendation as an order and shortly afterward clashed with other officials in Washington. His tilts with Harold L. Ickes, Robert P. Patterson, under secretary of war; James V. Forrestall, under secretary of the Navy, and Elmer Davis, director of OWI, made national headlines. With the first three the matter of materials was the issue. Jeffers wanted plants built for making rubber. Others wanted the same material for the Army, the Navy or for aviation-gasoline plants. His clash with Davis concerned conflicting reports as to progress in the synthetic-rubber program.

During the year he was in charge the synthetic rubber program changed materially from recommendations of the Baruch committee. The outstanding change was reduction in the number of conversion or "quickie" butadiene units. Despite changes and regardless of controversies over materials, the plants for making synthetic rubber made progress.

All units are scheduled for completion prior to the end of the year. The three, whose feed stock is dependent on 100-octane gasoline plants, are doubtless Cities Service Refining Corporation, Lake Charles; Neches Butane Products Company, Port Neches; Sinclair Rubber, Inc., Houston.

BRADLEY DEWEY

On the Pacific Coast the plant of Southern Counties Gas Company is in operation and those of Shell Chemical Company and Standard Oil Company of California are nearing completion. The three will furnish butadiene while Dow Chemical Company will provide styrene. One plant will combine these in the synthesis of Buna S rubber.

Construction work along the Texas Gulf Coast was hampered in July because of damage, especially to construction equipment, from a hurricane. Work was delayed while structures necessary for construction was replaced. Living quarters of workmen also had to be repaired. This delay was not sufficient to postpone completion of units longer than the end of the year.

Feed stock for butadiene units is so closely related to materials for blending 100-octane gasoline that the end of the year will bring most of the aviation gasoline capacity, as presently defined, into production. Although no announcements have been made, it is anticipated that additional 100-octane gasoline will be needed.

First approach to the increase doubtless will be gaining higher output from existing facilities. Operation of new units frequently uncovers methods of operating at rates higher than design capacities.

Additional construction is anticipated during 1944, the amount to be determined by success in operating plants now building and the needs of the military campaigns.

Meanwhile some new construction is already assured. One of the large construction jobs for the coming year will be for Petroleos de Mexicanos, Mexico City, where facilities will be provided for making high-octane motor fuel. Arrangements have been completed for financing the project through cooperation between the governments of United States and Mexico. The plant and reconditioning of a pipe line from the oil fields are scheduled to cost more than $15,000,000.

Purchase of additional land adjacent to its pipe line terminal at Puerto la Cruze, Venezuela, is the basis for assumption that Sinclair interests will build a refining plant where it can have advantage of recent crude oil reserves.

The first cycling plant for the Pacific Coast is now under construction in the Paloma field, Kern County, California. The venture represents a community interest with Western Gulf Oil Company, the Texas Company, Union Oil Company, Barnsdall Oil Company and Ohio Oil Company holding most of the field. A plant capable of handling 50,000,000 cubit feet of wet gas daily will be constructed by C. F. Braun & Company at a cost of $2,000,000. Completion is scheduled for February, 1944. The Paloma field is calculated to hold a reserve of 100,000,000 barrels of condensate.

Consideration is being given to an expansion of cycling facilities for the Katy field, near Houston. This plant of 200,000,000 cubic feet of daily capacity, was completed earlier this year. Expansion of the field, however, was substantial after plant specifications were drawn. Either additional facilities at the present plant or another cycling plant is having consideration.

Another cycling plant under consideration is that for the condensate field near Eagle Lake, Texas. Shell Oil Company is one of the major interests in this area.

Butadiene units yet to come on stream are: Cities Service Refining Corporation, Lake Charles; Neches Butane Products Company, Port Neches; Humble Oil & Refining Company, Baytown; Sinclair Rubber, Inc., Houston; Taylor Refining Company, Corpus Christi; Shell Chemical Company and Standard Oil Company of California in the Los Angeles project. Some of these may be completed in the latter part of September.

When these are functioning that part of the butadiene program from oil will be complete.

Since several of the butadiene projects are interlocked with aviation gasoline in that each comes from operation ot new catalytic cracking units, the aviation gasoline program will be augmented materially with completion of butadiene units.

Bureau Estimates 1943 Domestic Crude Oil Demand 6 Percent Up from Last Year

Substantial increases in the available supply of foreign oils from the Caribbean were indicated last week by the Bureau of Mines.

Commenting on the general situation, the bureau said the foreign oils apparently are supplementing our own increased crude supply. The need for such accessions was demonstrated by an estimate that domestic production this year may exceed the 1941 peak by at least 6 percent.

"The total demand for all oils was about 9 percent greater during the second quarter of 1943 than in the same period of 1942," it was stated. "The demand for both motor fuel and fuel oils was considerably larger than had been anticipated. Current trends indicate that the total demand for all oils will reach record levels in the third and fourth quarters of 1943.

"These unexpected demands have resulted in an abnormal seasonal decline in gasoline stocks, a continued steady shrinkage in stocks of residual fuel oil, and in relatively small seasonal gains in distillate fuel oil stocks. Further increments in demand must be met primarily by an expansion in new supplies. The recent sharp rise in domestic crude production and runs to stills is apparently being supplemented by similar gains in the available supply of foreign oils from Caribbean sources.

"In view of present trends, the domestic production of crude petroleum in 1943 may exceed the previous peak record of 1941 by at least 6 percent and crude runs to stills may at least equal the peak of 1941."

The bureau estimated that the market demand for domestic crude this month will average 4,210,000 barrels daily, an increase of 196,900 barrels, or 5 percent, over actual demand in September, 1942. The PAW certification for the month was 4,552,100 barrels daily of all petroleum liquids.

Daily average crude production for the four weeks ended July 31 was 4,111,000 barrels and total runs to stills 3,919,000 barrels, the bureau reported. During that period stocks of domestic crude declined 83,000 barrels daily, indicating a demand for domestic crude of 4,194,000 barrels daily.

By the middle of August, it was pointed out, crude production was substantially above 4,200,000 barrels daily and crude runs to stills had risen to over 4,000,000 barrels daily.

Total demand for motor fuel in September is estimated at 54,500,000 barrels, 5 percent more than the actual in the same month last year.

Stocks of finished and unfinished gasoline of 77,540,000 barrels on June 30 are indicated by American Petroleum Institute figures to have declined approximately 3,930,000 barrels during July and a further decrease of 1,700,000 barrels in finished stocks this month was estimated by the bureau.

Direct sales of natural gasoline and imports are estimated at 2,400,000 barrels, making an indicated refinery production of 50,400,000 barrels which the bureau distributed among the several refinery districts as follows:

East Coast, Inland Texas, Texas Gulf Coast, Louisiana Gulf Coast and Inland Louisiana-Arkansas, 24,000,000 barrels; Appalachian, 1,690,000 barrels; Indiana, Illinois, Kentucky, etc., 10,640,000 barrels; Oklahoma, 2,390,000 barrels; Kansas, 2,690,000 barrels; Rocky Mountain, 1,340,000 barrels; California, 7,650,000 barrels.

Benzol and natural gasoline to be blended at refineries was estimated at 5,160,000 barrels; the application of a yield of 37.7 percent to the straight-run and cracked gasoline production of 45,240,000 barrels gives crude runs of 120,000.000 barrels, or 4,000,000 barrels daily.

Crude oil for exports and to be used as fuel, and losses, was estimated at 7,100,000 barrels, giving an estimated demand for domestic crude of 126,300,000 barrels, or 4,210,000 barrels daily.

American Gas Association Plans Fall Meeting

Tentative program plans for the Twenty-Fifth Annual Meeting of the American Gas Association, to be held in St. Louis, Missouri, October 11, 12 and 13, are completed, and center about the problem of how the gas industry can more effectively serve the nation at war.

Arthur F. Bridge, president of the association and vice president and general manager of the Southern Counties Gas Company, Los Angeles, will preside at the general sessions. Ernest R. Acker, chairman of the committee on war activities and presidential nominee, and other notable gas industry men are expected to take a prominent part in the proceedings.

Under the direction of Burt R. Bay, chairman of the natural gas section and president of the Northern Natural Gas Company, Omaha, a program of timely interest and value is rapidly taking shape. Representatives of industry and government will speak on the most urgent problems and a new slate of officers will be elected. A special feature of this meeting will be the presentation of honorary memberships to pioneer natural gas men.

Mindful of the words of Acker, chairman of the committee on war activities, that "the war in which we are so fully and unequivocally engaged is a technicians' war," officers of the technical section have keyed their program to war developments. Two sessions will be held, the first, Monday afternoon, and the second, Tuesday morning.

Harold L. Gaidry, of New Orleans Public Service, chairman, will open the meeting with a review of the section's activities during the year. The latest advances in gas production, distribution and chemistry, including the work of important committees, will be covered by able speakers. Reports on research projects such as mixed gas, organic sulphur, and water gas will be made at this time.

Among the topics tentatively arranged for presentation are: "High Temperature Gasification," "Storage of Oil," and "Motor Vehicles and Emergency Conditions." It is also expected to have a symposium on post-war planning with Charles F. Turner, vice chairman of the technical section, presiding.

Of particular interest to distribution men will be a symposium on distribution studies embracing such subjects as "Tin in Solder," Microbiological Anaerobic Corrosion," and "Dissimilar Metals." This symposium will be led by H. B. Andersen, chairman of the distribution committee.

NPA Announces Program For New York Meeting

The program for the annual meeting of the National Petroleum Association in New York on September 21 and 22 has been announced. Sessions will be held in the Hotel Waldorf-Astoria. There will be departmental sessions each morning and technical sessions in the afternoon. Entertainment will consist of a fellowship banquet the evening of September 21.

The program for September 21 follows:

Department of Manufacture, M. C. Mallon, presiding, subject, "Base Oil Evaluation for Heavy-Duty Service.

Afternoon:

Address of H. A. Logan, president of the association.

"International Aspects of the American Petroleum Industry," Joseph E. Pogue, Chase National Bank.

"Wartime Refining Processes in the Post-War Era." Gustav Egloff, Universal Oil Products Company.

"The War, the Army and You," pictures and remarks on battlefield scenes by the War Department.

The program for September 22 includes:

Department of Traffic and Transportation, Harry E. Elkins, presiding.

"Refining," Bruce K. Brown, Assistant Deputy Petroleum Administrator for War.

"District 1 Problems," H. W. Dodge, director in charge of District 1, Petroleum Administration for War.

Mounting Military Demand Takes Third of Motor Fuel

A steadily expanding motor-fuel requirement by military forces now stands at nearly a third of the motor fuel produced east of the Rocky Mountains. For 1944 it will be 37.6 percent of gasoline production and the 1945 estimate is that 39.6 percent of all gasoline of this area will go into military consumption.

The figures were released in late August by Ralph K. Davies, deputy Petroleum Administrator for War, who pointed out that this growing need by the military is in large measure responsible for the reduction in civilian gasoline supplies in the Middle West and Southwest.

His summary revealed that in 1942 the military requirement was only 12.5 percent of gasoline produced. In the first quarter of this year it reached 21.4 percent, then climbed to 23.1 percent. For the last half of the year the estimate is 30.6 percent of the motor fuel produced east of the Rocky Mountains.

"These facts as to military requirements for gasoline add up to two fairly obvious conclusions," he said.

"The first is that it is going to take literally oceans of 100-octane and other

Aide-de-Camp to a

"CAT CRACKER"

*To Date...*37

Buell cyclones have been adapted for oil catalyst recovery in* 37 *catalytic cracking units.

Buell Dust Recovery Systems help make 100-octane gas...

"CAT CRACKER" is the oil industry's nickname for the new catalytic cracking processes now producing high-octane gas—processes calling for the highest efficiency in the recovery of catalyst dust. It is significant that so many leading oil companies have chosen Buell (van Tongeren) Dust Recovery Systems for this important work.

The remarkable natural and synthetic catalysts used are both expensive and abrasive. Buell equipment (incorporating the exclusive van Tongeren "shave-off") pays for itself many times over in the recovery of the costly, finely divided catalyst. And Buell's large-diameter, extra-heavy metal cyclones eliminate clogging and reduce abrasive wear—for long life and continuous performance.

Here, as in so many other fields, Buell leadership has again demonstrated its ability to solve difficult dust recovery problems.

For a complete description of the theory and operation of the Buell (van Tongeren) cyclone, write for Bulletin G-842.

BUELL ENGINEERING COMPANY, INC.
Suite 5000, 6 Cedar Street, New York 5, N. Y.
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buell
DUST RECOVERY SYSTEMS

BUY WAR BONDS AND MAKE THE AXIS BITE THE DUST

Amsco Alloy Still Parts Minimize Shutdowns and Production Losses

An important contribution has been made to the efficient, low cost refining of petroleum products by chromium-nickel alloy tube support castings. Without these heat and corrosion resistant parts, the continuous and economical operation of modern cracking stills would be much more difficult. When still parts fail, not only is the cost of new parts involved, but the resultant production delays are extremely costly.

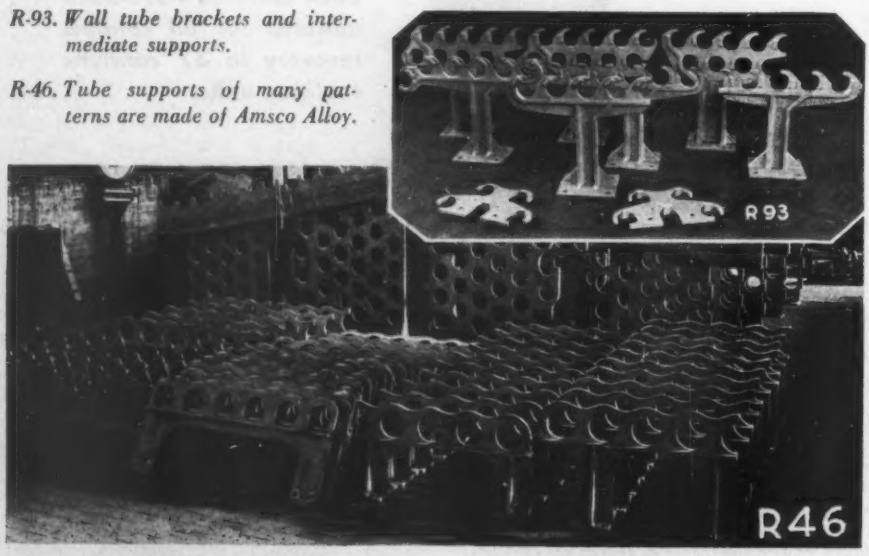
Amsco Alloy is extensively used in petroleum stills because it retains a considerable part of its load-carrying strength at the high temperatures encountered, and at the same time withstands the action of corrosive gases.

Amsco Alloy F-10 (26-28% chromium; 10-12% nickel) operates satisfactorily at temperatures up to 2000° F. It has proved economical in the form of tube supports, tube sheets, beams, channels, hangers, brackets and other still parts. The long life afforded by Amsco Alloy castings reduces replacements and shutdowns to a minimum in this important industry, at the same time saving critical metals.

May we send Bulletin No. 108, which contains the complete story of Amsco Alloy?

R-93. Wall tube brackets and intermediate supports.

R-46. Tube supports of many patterns are made of Amsco Alloy.



Amsco
AMERICAN MANGANESE STEEL DIVISION
Chicago Heights, Illinois
FOUNDRIES AT CHICAGO HEIGHTS, ILL.; NEW CASTLE, DEL.; DENVER, COLO.; OAKLAND, CALIF.; LOS ANGELES, CALIF.; ST. LOUIS, MO.
OFFICES IN PRINCIPAL CITIES

AMERICAN Brake Shoe COMPANY

highly specialized engine fuels to fight this war to a victorious conclusion.

"The second is that as military requirements increase it is inevitable that there will be less gasoline available for civilian consumption.

"It seems patent to the petroleum administration — and oil industry leaders have publicly agreed — that the only means whereby those needs can be met in full is to reduce correspondingly the demands on our gasoline stocks at home. That is the basic reason why it has been found necessary to reduce the consumption of gasoline in the Middle West and Southwest."

Commercial Production Of Triptane Announced

Commercial production of triptane (2,2,3 trimethylbutane) has been announced by Universal Oil Products Company, Chicago. Discovery of a catalytic process to provide quantity output of this formerly expensive hydrocarbon is the work of Dr. V. N. Ipatieff, the company's director of chemical research and Dr. Vladimir Haensel, research chemist. Of the product the announcement was:

"Its anti-knock properties are of such magnitude that no commercial engine has been built which is capable of utilizing the full value of pure triptane. When used as a component of aviation gasoline, it greatly enhances the performance of present-day aircraft engines and makes possible the design of future engines of even greater power and efficiency.

Only limited details were given of the process. Previously it could be produced only by the Grignard reaction and its cost was around $3,000 per gallon. The announcement gave this additional information as to process.

"The process consists of two steps. The second step of the process involves the formation of triptane from a selected charging stock produced in the first step. Based on the material charged to the second step, liquid recoveries of over 90 percent are obtained of which over 50 percent is triptane.

"The process, when operated to make the largest quantity of triptane available as a blending agent, yields two other valuable hydrocarbons, in themselves of great value in aviation blends. These hydrocarbons, 2,3-dimenthylbutane and 2,3-dimenthylpentane, are superior to alkylate as blending agents for aviation gasoline.

"The following are physical properties of individual hydrocarbons produced by this process:

"The relatively high freezing point of pure triptane does not preclude its use in aviation fuels. Blends containing up to about 85 percent triptane do not freeze above —78°C. (—108°F.).

"The product of the reaction is saturated and free of impurities so that no additional refining treatment is necessary to permit its use in aviation fuels. The process has been operated to date for 300 hours in a pilot plant with no indication of decline of catalyst activity.

"No new or unusual materials are needed for the reaction or process. The raw materials are condensable gases produced in petroleum refineries as by-products of catalytic and non-catalytic cracking or reforming of petroleum

It's just horse sense that a "horsepower" Steam Turbine sized right for the job saves metal for war and money for you while an "Elephant Power" Turbine too big for the job wastes both. COPPUS Blue Ribbon Turbines come in six frame sizes from 150 H. P. down to fractional. Each smaller size requires less metal and is priced less. The "Blue Ribbon" certifies prize-winning COPPUS performance.

COPPUS TURBINES

Save Metal in Wartime — Will Save You Money in Peacetime

Like all Coppus "Blue Ribbon" Products (blowers, ventilators, gas burners, etc.), the Coppus steam turbine is a precision-made product . . . controlled by Johansson size blocks . . . and every turbine is dynamometer-tested before shipment. More than 85% of all orders since 1937 have been repeat orders.

Write for Bulletin 135-9

COPPUS ENGINEERING CORPORATION
419 Park Avenue, Worcester, Mass.
Sales Offices in THOMAS' REGISTER
Other "Blue Ribbon" Products in
REFINERY CATALOG.

COPPUS

BLUE RIBBON PRODUCTS

DESIGNED FOR YOUR INDUSTRY . . . ENGINEERED FOR YOU

Simplicity of Design
Means Easier Maintenance

Easy Servicing - -

A Help for
the Maintenance Man

So simple in design, so sturdy in construction, so resultful in lasting-ability is the "King-clip" Valve, only a minimum of maintenance is required to keep it in good working order.

And when service is required, the ease with which the valve can be disassembled for inspection and repairs, is a real time and labor saver. Any maintenance man knows that this provision for quick servicing is a long step toward the uninterrupted production hours he is striving for.

"KING-CLIP" GATE VALVE

A further aid to the attainment of easier and more efficient maintenance is the precision-gauged manufacture of replacement parts, assuring an exact duplicate of any part that may have to be renewed.

A Lunkenheimer distributor is near you to help you get what you need. His complete facilities are at your service.

Here's how easily the "King-clip" valve can be disassembled - - -

Unscrew two nuts at top of clip and entire bonnet-stem-disc assembly can be lifted from the body. Complete accessibility for inspection or repairs is the work of a few minutes. - - - Circular 504 fully describes the "King-clip" valve. Ask for a copy or write us direct.

ESTABLISHED 1862
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LUNKENHEIMER VALVES

oils. The catalysts are readily available in large quantities. No special equipment or materials used in the process plant are necessary other than regular equipment employed in refineries. The temperatures and pressures employed are well within refinery experience."

P. O. Foster is Manager of Shell's Houston Plant

P. O. Foster was recently named manager of Shell Oil Company's refinery, at Houston, succeeding Dr. R. H. Waser, who goes to the New York headquarters.

Previous to his new assignment, Foster was manager of the Norco refinery at Baton Rouge, Louisiana. His first connection with Shell was at the Martinez, California, Loading rack, in May, 1916. Since that time he has had various assignments with the company, and also was in England for a period.

He returned to the Shell in 1924 and had a six months assignment at Norco, followed by a transfer to Wood River as second assistant superintendent. In October, 1928, he was advanced to the superintendency of the Arkansas City plant, and two months later transferred to the Norco refinery where he remained up to August 2, 1943, with the exception of six months on special assignment in Balik-Papen, Borneo.

Reeder Named Manager of Union Oil Company Plant

J. C. Reeder has been appointed manager of the Los Angeles refining plant of Union Oil Company. He succeeds Ray G. Bray, who died in Washington in June. Bray was on leave from Union Oil Company and was on the staff of the director of refining in the office of the Petroleum Administration for War at the time of his death.

Reeder was superintendent of operation at the Los Angeles plant and became acting manager when Ray went to Washington.

Smith in Charge Of Kendall Plant

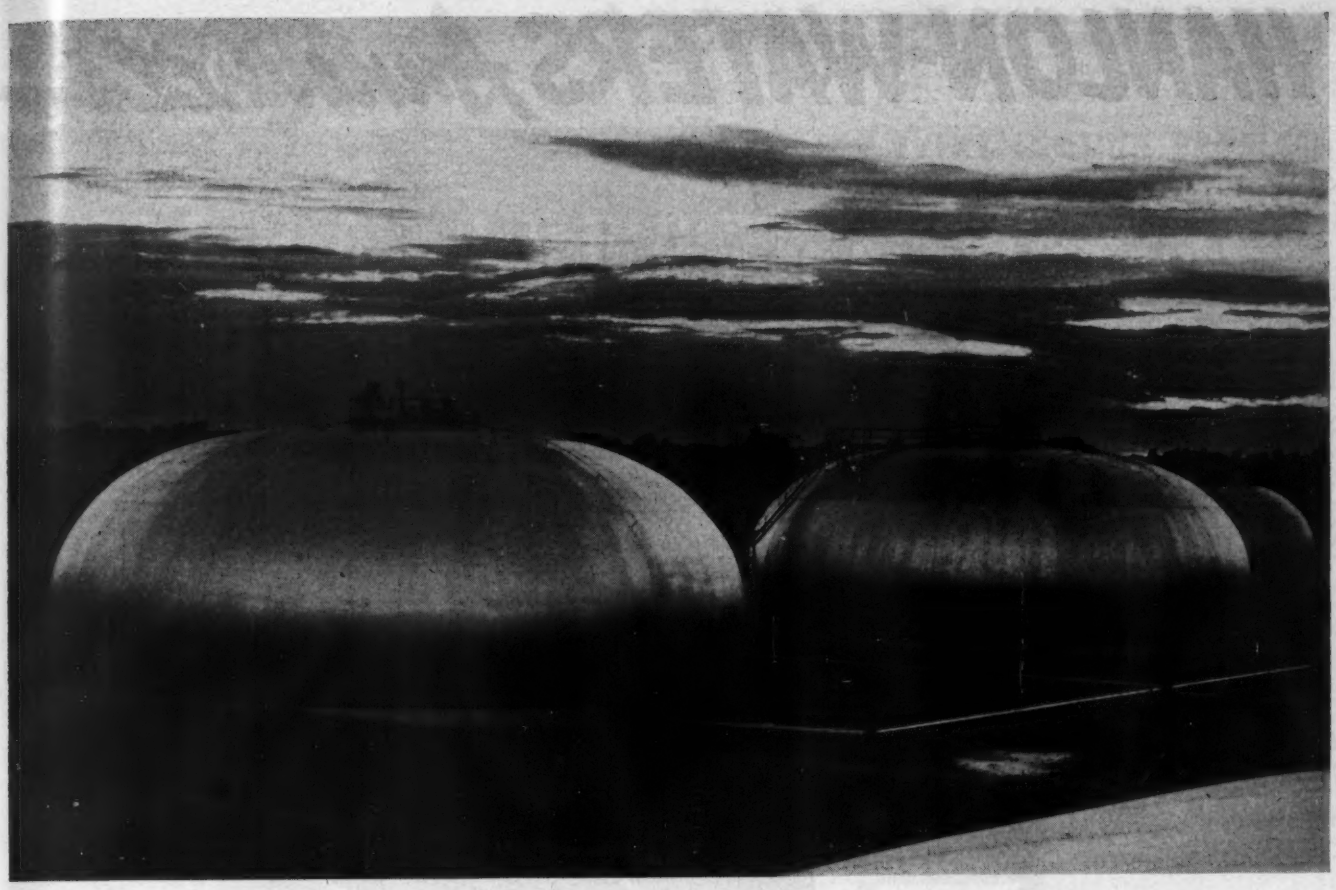
Howard V. Smith has been appointed superintendent of the refining plant of Kendall Refining Company, Bradford, Pennsylvania. He succeeded W. B. McCluer, who resigned July 1 to become associated with Rohm & Hass Company, Philadelphia.

Smith is a graduate of the University of Kansas in chemical engineering. He was with Skelly Oil Company, El Dorado, Kansas, for 14 years, being assistant superintendent for 11 years. In 1938 he joined Barber Asphalt Company. Recently he was with The Lummus Company.

Buc Retires From Standard Development

Hymn E. Buc, discoverer of a mosquito repellent widely used by United States armed forces, and first organic research chemist employed by Standard Oil Development Company, has retired from that organization after more than 23 years of service. Buc, a resident of Roselle, New Jersey, was recently honored guest at a dinner given by his fellow employes to mark his long service with the group. He has been awarded a life annuity by the company.

During his career with Standard Oil



HORTONSPHEROIDS

help Marketing Terminals

. . . MEET EMERGENCIES IN WARTIME

IN peacetime, marketing terminals help provide efficient, economical distribution of petroleum products for the nation's oil companies. In times of war these marketing stations assume even greater significance. For marketing terminals may be called upon to meet the immediate demands of a given area *even when transportation of petroleum products has been temporarily suspended.* Adequate storage facilities to hold stocks of gasoline and other products in reserve can aid immeasurably in meeting this problem.

Marketing organizations have found that the Hortonspheroid can provide the type of storage necessary to efficiently handle distribution during emergencies. These tanks are usually designed to withstand pressure of several pounds per square inch to stop evaporation loss by breathing and prevent lowering of volatility of the products stored.

Shown above are three Hortonspheroids located at an eastern marketing terminal. One has a capacity of 6,000 bbl. and two have a capacity of 50,000 bbl. each for 2½ lbs. pressure. One Hortonspheroid of 80,000 bbl. capacity for 1½ lbs. pressure is used at a nearby terminal, not shown.

. . . Awarded to our shipyard at Seneca, Ill., and dry dock yards at Eureka, Calif., and Newburgh, N. Y.

CHICAGO BRIDGE & IRON COMPANY

San Francisco 5	1019 Rialto Bldg.	Tulsa 3	1603 Hunt Bldg.
Birmingham 1	1542 N. Fiftieth St.	Cleveland 15	2237 Guildhall Bldg.
Chicago 4	2491 McCormick Bldg.	New York 6	3368-165 Broadway Bldg.
Havana	402 Edificio Abreu	Philadelphia 3	1611-1700 Walnut St.
Houston 1	5622 Clinton Drive	Washington 5	330 Bowen Bldg.

Plants in BIRMINGHAM, CHICAGO and GREENVILLE, PENNSYLVANIA

HANLON-WATERS Announces—

an OUTSTANDING

Simplified-Reversibility

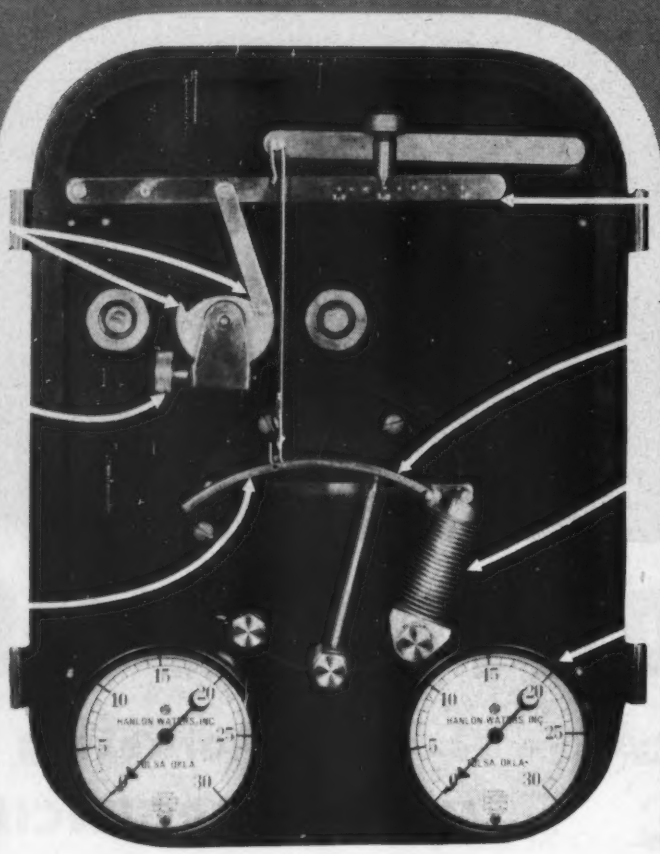
Adjustment for height of Level Control.

"Snap Action" settings on Pilot without use of any additional parts or special tools.

Wide swinging door — easy accessibility of all parts.

Mountable on any H-W Type 850 Displacement Level Control.

Equipped with the popular H-W Type 245 Supply Medium Regulator.

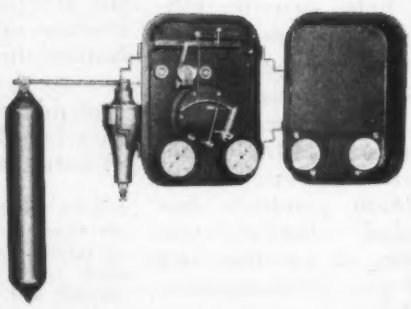


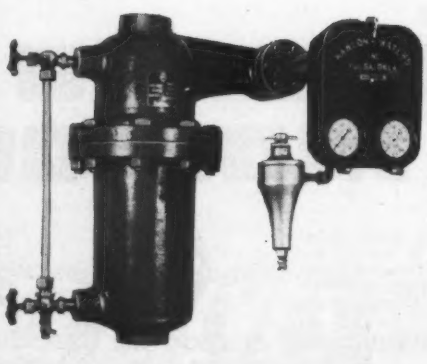
Specific gravity index scale setting from .10 to 2.0.

WIDE THROTTLING RANGE adjustment from Zero to 300% —setting in exact relation to specific gravity setting.

Long life bellows, operating throttle arm.

Straight line pilot characteristic of pressure output to diaphragm vs. level variation.





H-W New Type 1410 Level Control Pilot is especially designed to meet requirements for a Level Control Pilot having a VERY WIDE "Throttling Range" — EXACT in its relation to the specific gravity of the liquids handled in the system. Important for indicating or recording level service where the displacement float is used to indicate position of level in vessels where highly corrosive liquids make continuous use of gauge glasses impossible.

ASK THE MEN WHO OPERATE THEM!

DEVELOPMENT IN *Level Control Pilots* for

- REFINING
- CHEMICAL
- SYNTHETIC
- GASOLINE
- RECYCLING and
- POWER INDUSTRIES

THE LEVEL CONTROLLER WITH **no** STUFFING BOX . . . . . LEAKAGE . . . . . FRICTION

WIDE-THROTTLING RANGE settings are most important for even-flow characteristics where surge impulse elimination raises efficiency and makes for better control of the system. "Snap-Action" settings are easily made without additional parts or special tools, if "on-off" action of control valve is desired.

Features of the Type 1410 Level Control assure performance matching other H-W Control Equipment that are—

STANDARD FOR *Performance*

Hanlon-Waters, Inc.

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Information on all HANLON-WATERS Equipment is available at representative nearest you.

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FOR EVERY CONTROL PROBLEM you CAN DEPEND on H-W Automatic Control Equipment

3" Standard FG Type 60 LEVER VALVE

6" FG Type 1500 BUTTERFLY VALVE

1" SG Type 15-DRT MOTOR VALVE

Type 86-F MOTOR VALVE

8" Std. FG Type 86 MOTOR VALVE

2" Std. Type 97-RF Duplex Diaphragm Regulator

"The life and soul of science is its practical application."
—Lord Kelvin

1811-1899
Robert Wilhelm von Bunsen was a notable chemist whose one exploration in physics resulted in determining the vast amount of furnace heat lost with waste gases.

His invention of the Bunsen Burner, the principle of which is incorporated in every burner employed in various arts and manufactures, was a notable contribution to science.

Discoveries of the scientists of the past result in the applied engineering of the present. Alcorn, for 19 years, has used scientific discoveries, engineering skill and knowledge of processing requirements for the solution of the many specialized demands for the application of heat to petroleum products refining. For every type of installation, low temperature or high, Alcorn's pioneering has resulted in the design and construction of heaters for efficient, economical, controlled operation.

ALCORN
Combustion Company

SCHAFF BUILDING, PHILADELPHIA
Los Angeles • Houston • San Francisco

Development Company, Buc was issued 56 patents and has 64 applications still pending. His work ranged from discoveries lengthening the life of motor oil in automobiles to removing the offensive smell from industrial alcohol, and included both abstract scientific investigation and determination of practical research standards such as the use of fish for testing the effectiveness of insecticides.

"Fuel Oil and Its Combustion"

"Fuel Oil and Its Combustion" is the title of a new book published by the Research Department of The North American Manufacturing Company, 2910 East 75th Street, Cleveland, Ohio.

A scholarly and thorough synopsis of data pertaining to fuel oil is presented. Chapters include: Crude oil constituents and classification; crude oil processing; properties of fuel oils; fuel oil combustion; summation and conclusion.

There are also various charts, graphs and tables giving specific and detailed data.

Copies are available from the company, at $1.50 per copy.

Correction

An error in the manuscript of "Use of Interrupting Devices in the Clearing of Electrical Circuits," Wyman A. Holland, carried through into publication on page 105 of the July, 1943, Petroleum Refiner.

The error is in the denominator of the formula under conversion of ohms to PU. The figure 2 should have been a superior designation to denote volts squared rather than volts times 2.

Use of the formula should be with this correction.

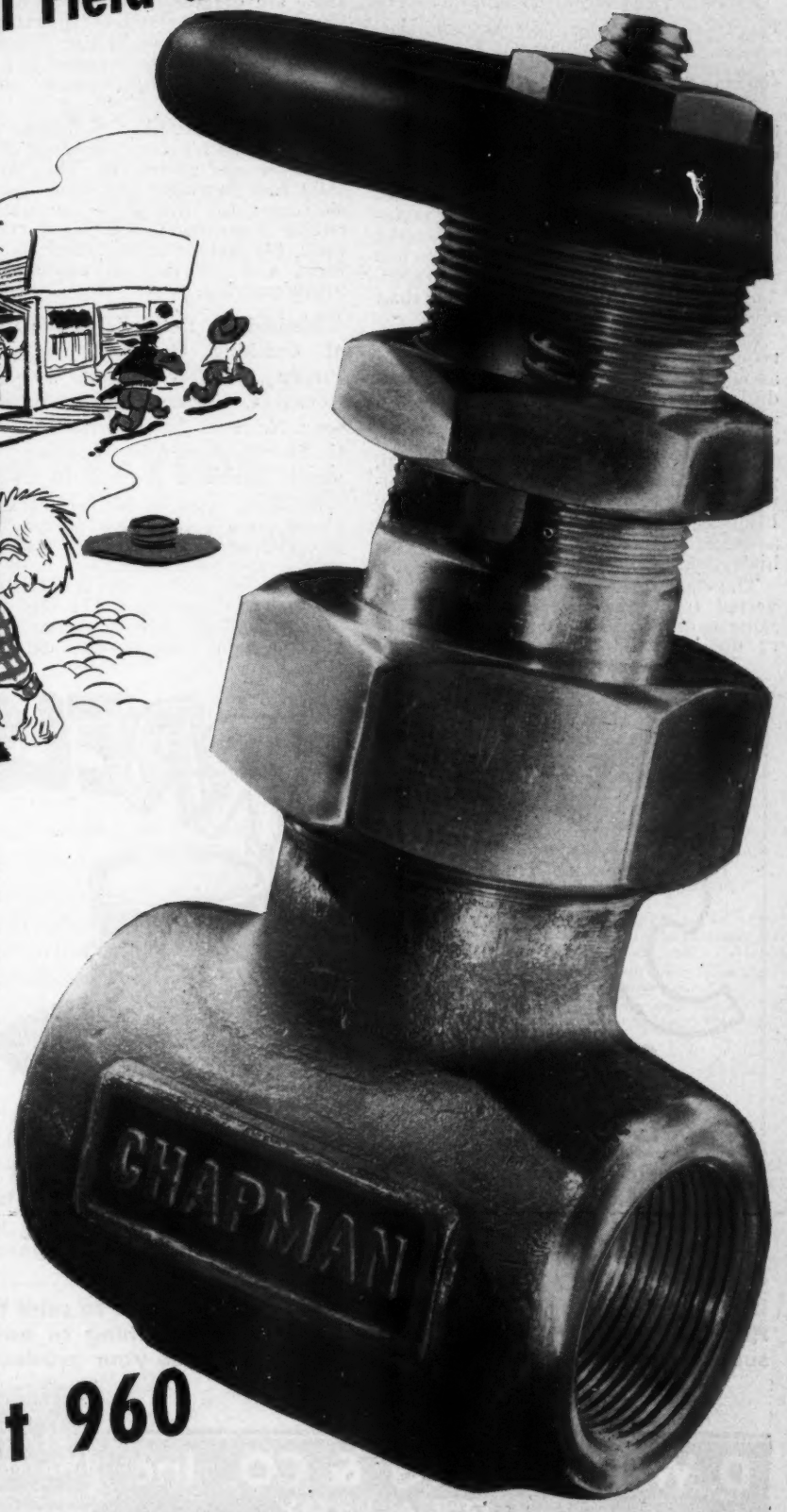
Linan and McDuff Join Rubber Reserve

Henry Linan, formerly president of Standard Oil Company of Venezuela, and Homer McDuff, formerly drilling superintendent for that company in Eastern Venezuela, both have accepted positions with Rubber Reserve Corporation, Linan as an executive vice president and McDuff in charge of some special work in Brazil. Linan resigned his position as president of Standard Oil Company of Venezuela several months ago, and McDuff, after being with the company several years in Venezuela, returned to the United States in 1941 and has since that time been in Louisiana and Oklahoma. He left for Brazil last week.

Henry Linan

Homer McDuff

Here's Your Keeper of Law and Order on Small Field and Refinery Lines



All the usual small-valve troubles hit for the tall timber when Chapman List 960 takes over on lines from ¼" to 2". Wear is kept under strict restraint by tough steel plugs and seats . . . which may even be super-hardened by an exclusive Chapman process, if your service is out of the ordinary. And there's never any balking in operation, for the quick-acting threads can't stick, strip or jam. As for repacking, that's easily done under full pressure with the valve open. Chapman List 960 is okay for all pressures up to 800 lb. at 750° F., and up to 1500 lb. cold working pressure. Standardize on List 960 . . . and there will be no "disturbance of the peace" on *your* lines.

The CHAPMAN VALVE MFG. CO.
INDIAN ORCHARD, MASS.

CHAPMAN List 960

Subdues all Small-Valve Troubles

ABSTRACTS OF PAPERS BEFORE DIVISION OF PETROLEUM CHEMISTRY OF THE AMERICAN CHEMICAL SOCIETY

Pittsburgh, Pennsylvania, September 6-10, 1943

Producer Gas Motor Vehicles. GUSTAV EGLOFF AND PRUDENCE VAN ARSDELL, *Universal Oil Products Company, Research Laboratories, Chicago.*

The war years 1914-1918 gave the impetus to the development of the producer gas, for the same reason—lack of petroleum—that is prevalent today. The producer-gas vehicle had its greatest development in countries having no material petroleum production. The present estimate of the number of producer gas vehicles in the world is over 600,000. This is about 50 percent greater than the number at the end of 1941.

Producer-gas engines are of four types, the updraft, where the fuel and air move counterflow, and the downdraft, in concurrent flow, the cross draft, and the double draft. All types are in operation.

The fuels used are wood, charcoal, peat, brown coal, lignite, anthracite, bituminous coal, flax waste, sawdust, straw briquets, and waste wheat. There is not a single continent on which these vehicles are not used.

The compression ratios of engines converted from gasoline use may be the same as or as high as 10 to 1. The weight of the gas-producer equipment varies, some are greater than 1000 pounds, depending upon the type of installation—i.e., truck, bus, or family car. The weight of the engine per horsepower is 7 to 10 pounds when using producer gas installations.

There are a number of factors affecting any country converting gasoline to producer gas utilization. They are (1) solid fuel shortage; (2) steel and alloy shortage; (3) manpower shortage for engine conversion and production of fuels, (4) lack of transportation of solid fuels, and (5) lack of equipment for manufacturing.

Method for Determining the Activity of Cracking Catalysts. CHARLES L. THOMAS, GUSTAV EGLOFF, AND JAMES HOEKSTRA, *Universal Oil Products Company, Research Laboratories,* and WILBFR C. SHAND, *Blaw-Knox Company, Baton Rouge, Louisiana.*

A 25-cc. sample of the catalyst is placed in a special reactor tube and a gas oil fraction passed over the catalyst at the rate of 100 cc. per hour for 2 hours at 500° C. The gas is collected and the weight determined. The liquid product is distilled to remove the gasoline and the weight of gasoline determined. The yield of gas plus gasoline as weight percent of the charge is used as a measure of the activity of the catalyst. A sample of standard catalyst is employed to define an activity curve which is used for evaluating the activity of catalysts in terms of the standard catalyst.

Recovery of Sulfur from Sulfur Dioxide in Waste Gases. T. F. DOUMANI, R. F. DEERY, AND W. E. BRADLEY, *Union Oil Company of California, Wilmington.*

Elementary sulfur has been recovered from sulfur dioxide-containing gases by a two-step catalytic process operating at atmospheric pressure. Wet gases containing relatively low percentages of sulfur dioxide can be treated. The principal reactions are represented by the following equations:

$$2\,SO_2 + 4\,H_2 \rightleftharpoons S_2 + 4\,H_2O \quad (1)$$

$$H_2 + S_2 \rightleftharpoons 2\,H_2S \quad (2)$$

$$3/2\,S_2 + 2\,H_2O \rightleftharpoons 2\,H_2S + SO_2 \quad (3)$$

$$2\,H_2S + SO_2 \rightleftharpoons 3\,S + 2\,H_2O \quad (4)$$

In step 1 (equations 1, 2, 3), the sulfur dioxide-containing gas is mixed with hydrogen and passed through a catalyst bed at temperatures above 300° C. A gel-type catalyst comprising about 25 percent iron sulfide and 75 percent alumina is effective. In step 2 (equation 4) complete conversion to elemental sulfur is accomplished by passing the mixture of hydrogen sulfide and sulfur dioxide from step 1 over activated alumina at temperatures of 100° to 200° C. The sulfur tends to deposit in the catalyst bed and eventually deactivates the catalyst. Reactivation of the latter is readily accomplished by raising the temperature of the catalyst bed above 500° C.

An Automatic Distillation Apparatus for Gasoline Analysis. LESTER STEFFENS AND DONALD P. HEATH, *Technical Service Division, General Laboratories, Socony-Vacuum Oil Company.*

Precise distillation is one of the major tools available for gasoline analysis, but operation at the necessary high reflux ratios results in a time requirement of as long as several weeks for distillation of a single sample. To expedite such work, an automatic distillate collector was constructed for use with a Podbielniak Super-Cal distilling apparatus, to permit continuous operation with a minimum of attention from the operator. Successive distillate fractions are measured in a float chamber and emptied automatically into bottles. The boiling point of the distillate is recorded continuously. The apparatus can be operated for a 16-hour period without attention from the operator.

Sulfuric Acid Extraction in Hydrocarbon Type Analysis. C. C. ALLEN AND H. W. DUCKWALL, *Anderson-Prichard Research Laboratory, Cyril, Oklahoma.*

Sulfuric acid absorption experiments were carried out on a paraffin-naphthene-kerosene fraction containing known proportions of various benzene and naph-

An oil refinery operating a condenser cooling system found that scale in condenser tubes was slowing up production. Haering engineers were called in to make a survey. Haering Glucosates were applied. In a short time scale began to disappear and gasoline production went up 50 barrels a day.

It may be costing you more than 50 barrels a day not to send for a Haering engineer. Anyway, it won't cost you anything to have a survey made. Why not find out if we can increase your production.

Write for "Cooling Waters"

WE READ WATER

D. W. HAERING & CO., Inc.

GENERAL OFFICES

205 West Wacker Drive Chicago, Illinois.

Winning the "*Battle of Production*" involves a lot more than a supremacy of materials, machinery and manpower. One major fire . . . or a small fire that results in crippling damage by the extinguishing medium . . . can halt or slow down war production in a dozen vital plants.

Cardox Fire Extinguishing Systems are guarding against these crippling fires in plants producing a wide variety of critical war products. For example, individually engineered applications are on duty in important plants producing such military necessities as:

Airplanes, Aviation Engines, Aviation Carburetors, Airplane Parts, Engine Parts, Plastics, Rubber Products, Processed Fabric, Tanks, Tank Engines, Cold Strip Steel, Armor Plate, Forgings, Solvents, Motor Fuel, Electric Power.

By instant smothering of fire and cooling of combustibles through the mass discharge . . . at high rate of flow . . . of low pressure, low temperature CO_2, Cardox Systems provide the all-important advantage of fast, complete extinguishment of large or small fires—without damage by the extinguishing medium.

Today, Cardox is concentrating its engineering and manufacturing facilities on two basic activities: (1) Designing and manufacturing of Cardox Fire Extinguishing Systems needed to make it possible for the Armed Forces of America to have more planes, guns, tanks and ammunition; (2) working with industry on plans to increase the efficiency of fire protection both today and after the war.

If you would like more information, write on company letterhead for Bulletin 2493.

CARDOX CORPORATION
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★ ***BUY WAR BONDS*** ★

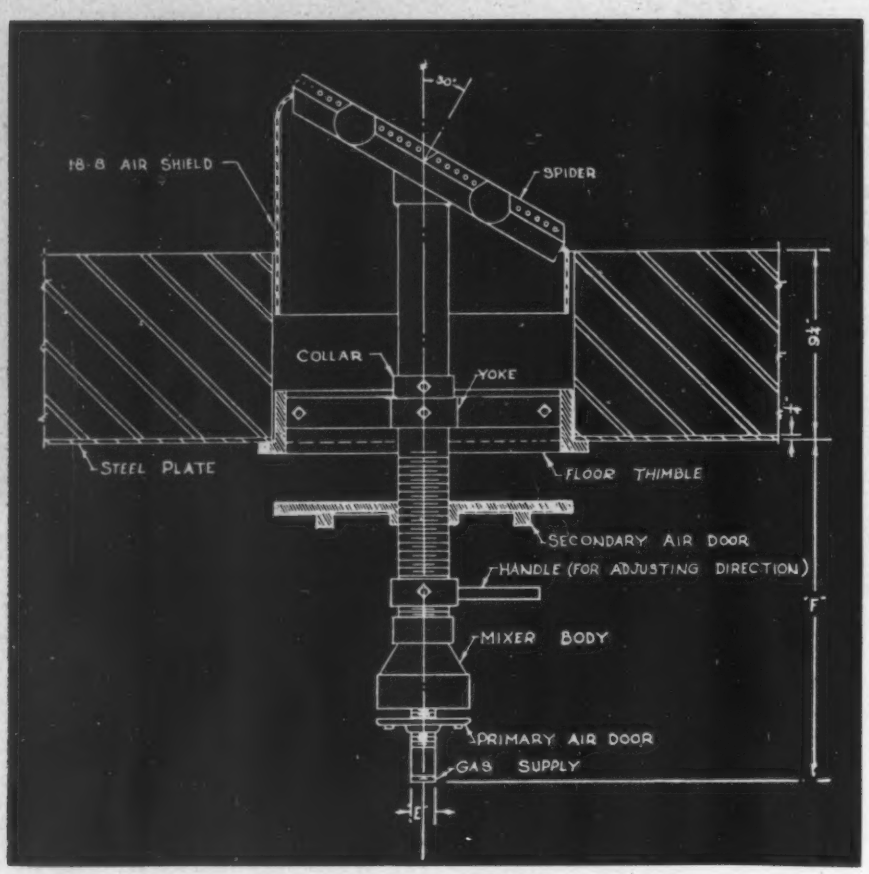
How Cardox Systems Protect War Industries

- **Timed discharges, as needed, through built-in piping systems . . . supplied instantly from a single storage unit holding tons (if required) of liquid Cardox CO_2.**
- **Mass discharge of Cardox CO_2 "knocks out" fire, by . . .**
- **Reducing oxygen content of the atmosphere below the concentration necessary for combustion, and . . .**
- **Cooling combustibles and fire zone below ignition temperature . . .**
- **Extinguishing fire quickly and completely *without* damage from extinguishing medium.**

CARDOX—CO_2 Systems with Enhanced Fire Extinguishing Performance

A. Uniformity of CO_2 characteristics.
B. Extinguishing medium with uniformly greater cooling effect.
C. Accurate projection of CO_2 through greater distances.
D. Timed discharges, as needed, through built-in piping systems . . . supplied quickly from a single tank holding tons of liquid Cardox CO_2.

the JOHN ZINK BI-MIX DIRECTIONAL HEAT BURNER



(PATENT APPLIED FOR)

- Because Heat Placement is so important in modern processing this new burner is designed to:

  Place the heat where you want it,
  When you want it.

- The burner is so adjustable that the operator can turn the burner to place the heat where desired.
- This burner will be furnished as a gas burner only or as a combination oil and gas burner.

The John Zink FOUNDRY has the experienced supervision and facilities to make light castings involving numerous small cores.

JOHN ZINK COMPANY

TULSA, OKLAHOMA

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thalene derivatives. It was found that employing several different ratios of 101 percent acid to oil and extrapolating to zero acid to oil ratio, the complications due to incomplete removal of unsaturates, solubility of saturates in the extract, and attack of the acid on the saturates could be avoided. The data obtained on hydrocarbon mixtures and the saturated sulfuric acid raffinates by the extrapolation method could be combined to give information on the unsaturated constituents.

The Permeability of Hydrocarbon Gases Through Rubber Tubing. J. R. RILEY, M. J. STROSS AND H. M. EBY, *Universal Oil Products Company Laboratories.*

Hydrocarbon gas permeation for planar films of rubber varies inversely with thickness of the film and directly with the area. Likewise, permeation of gases through rubber tubing varies directly with the inside diameter, and inversely with the wall thickness.

For a single type of rubber tubing, the permeability of different gases varies over a wide range. In general, olefins permeate rubber more rapidly than paraffins; hydrocarbons of the C_4 range much more rapidly than those of lower molecular weight.

Synthetic rubbers—e.g., neoprene and particularly Koroseal—are far less permeable than any compounds of natural rubber tubings. Plastic tubings such as Resistoflex are much superior than either synthetic or natural rubber. Synthetics of the Buna and Butyl type were not investigated.

Potentiometric Determination of Acidity in Highly Colored Materials. Application to New and Used Petroleum Lubricants Containing Additives. LOUIS LYKKEN, P. PORTER, H. D. RULIFFSON, AND F. D. TUEMMLER, *Shell Development Company, Emeryville, California.*

Potentiometric methods applicable to the determination of free and combined acidity of materials soluble only in a non-aqueous solvent are presented; the methods are particularly applicable where acidimetric color titration indicators fail—that is, to highly colored or opaque materials such as used lubricants or lubricants containing oxidation and corrosion inhibitors, detergents, fats, and other additives. Although the methods were developed primarily for use in the study of the oxidation characteristics of lubricating oils, the principles, apparatus, and procedures are applicable to a large variety of other materials such as asphalt, emulsions, resins, polymers, animal and vegetable fats, oils, etc.

Titration is made directly or after saponification with potassium hydroxide in a single-phase solution of the sample in a non-aqueous solvent (benzene-isopropyl alcohol) containing approximately 0.5 percent water, using a glass-calomel electrode system. Inflection points and fixed cell potentials are used for the estimation of end points. The determination by a single titration of two or more components of a mixture of acids of bases not distinguishable in an aqueous titration, and phenomena which make possible the estimation of ionization constants of acids and bases having

100 OCTANE GASOLINE *Depends on Instruments Like These—*

IN THE operation of the new Fluid Catalytic Cracking Plants of the Standard Oil Company of New Jersey, a new refining technique has been perfected which provides for the simultaneous production of synthetic rubber raw materials and an improved quality of 100-Octane Gasoline.

In selecting and arranging equipment for these new refineries, nothing was spared to make these plants a model of efficiency and ease of operation.

Helping to maintain operating efficiency are Brown Air-O-Line Recording Controllers (shown above) in the Central Control Room of the Fluid Catalytic Cracking process.

It is a tribute to Brown's engineering that leading refineries depend on Brown Instruments for precision control of temperatures, pressures, flows and liquid levels in the production of 100-Octane Gasoline.

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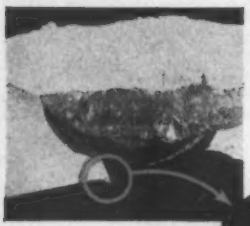
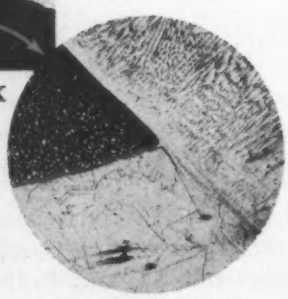


Magnification 10X



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Macrograph shows pure deposited nickel at base of weld before any alloying. Photo micrograph in circle shows characteristics of deposited pure nickel, of original clad nickel, of original steel to which nickel was clad.

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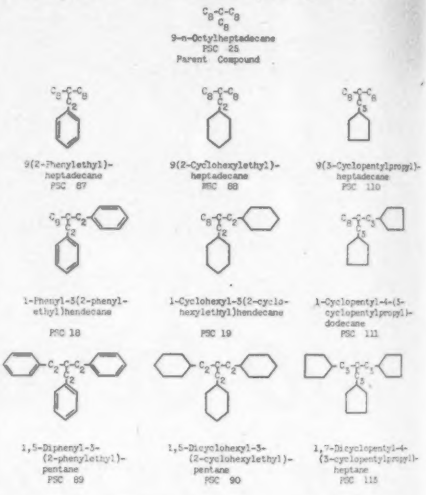
limited solubility in water are briefly described.

The Effect of Cyclization on the Properties of Higher Hydrocarbons. R. W. SCHIESSLER, *Pennsylvania State College;* D. G. CLARKE, *Rohn & Haas Co., Philadelphia;* C. H. HERR, *Pennsylvania State College;* F. C. WHITMORE, *Pennsylvania State College,* and J. N. COSBY, *General Aniline and Film Company, Westfield, New Jersey.*

In order to study the effect of progressive cyclization on the physical properties of hydrocarbons of high molecular weight, three series of methanes substituted with three 8-carbon groups have been synthesized. The basic symmetry of the molecules and the molecular weights have been maintained as constant as possible, thus allowing a better comparison of the relative effects on physical properties of the phenyl-, cyclohexyl-, and cyclopentyl- groupings.

Following are the names and skeletal structures of the hydrocarbons which compose the three series (a notation such as C_8—refers to an unbranched, saturated chain of eight carbon atoms, with their substituent hydrogens):



Substituted Methanes C_x denotes a straight carbon chain of x carbon atoms.

The following physical constants are reported for each of the hydrocarbons: melting point or pour point, boiling point at 1.00 mm. pressure, viscosities in centistokes and Saybolt seconds at 100° and 210° F., kinematic viscosity index (Dean and Davis), density at 68° F., refractive index at 68° F., and aniline point.

Tentative conclusions are drawn concerning the effect of cyclic structures on physical properties.

Bicyclo [2,2,1] Heptane and Bicyclo [2,2,1]-2-Heptene. CHARLES L. THOMAS, *Universal Oil Products Company.*

Bicyclo [2,2,1]-2-heptene was formed by heating technical dicyclopentadiene with ethylene in a bomb at 200° C. and at pressures up to 120 atmospheres. Presumably the dicyclopentadiene depolymerizes to cyclopentadiene and this reacts with the ethylene under the reaction conditions to give the bicycloheptene.

Bicyclo [2,2,1] heptane was formed by hydrogenating the bicycloheptene at 50° C. in the presence of a nickel catalyst. A small amount of methylcyclohexane was formed at the same time.

Both of these compounds are white crystalline solids.

A.S.T.M. octane numbers were deter-

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mined on blends of 2,2,4-trimethylpentane, n-heptane, and the hydrocarbon. The bicycloheptene had a blending octane number of 95 ±5, and the bicycloheptane, 56 ±5.

Liquid Densities of Volatile Hydrocarbon Mixtures. G. H. HANSON, *Phillips Petroleum Company,* and R. D. KUIST AND G. G. BROWN, *University of Michigan.*

The use of apparent densities for methane and ethane in the liquid phase, suggested by Standing and Katz for estimating the density of crude oil saturated with natural gas at high pressure, has been extended to liquid mixtures of volatile hydrocarbons as found in natural gasoline. The results agree with the experimental data in a satisfactory manner. At the present time this appears to be the most reliable method for estimating the density of liquid petroleum and natural gas mixtures from the composition of the mixture.

Furfural Solution Temperatures of Hydrocarbons. I. Evaluation of Mixed Aniline Point Determination and Application of Furfural. HARRY T. RICE AND EUGENE LIEBER, *Standard Oil Company of New Jersey, Bayonne.*

The solvency characteristics of various petroleum fractions of the type of solvent oil, solvent naphtha, Diesel fuels, various gas oils, etc., constitute an important index as to the properties such products will display in use. The determination of these characteristics has been an important task of the petroleum technologists, and various methods have been devised for their evaluation. Of these methods, those based upon the miscibility solution temperature of the oil and a solvent liquid are among the most important.

Of the various types of solvents proposed for this determination, aniline appears to have been accepted as the standard. This material has several defects which make it desirable to find a more widely acceptable substitute. For one thing, it is an extremely toxic blood poison.

Its chief disadvantage, however, arises from the fact that it cannot be used for the determination of the miscibility solution temperature of highly aromatic petroleum fraction, because of its relatively high freezing point.

In an effort to circumvent this shortcoming, the so-called "mixed aniline point" has been introduced for evaluating these materials. This test is unstandardized and is completely meaningless as it is now used. The need for it can be eliminated by replacing the aniline with a solvent of lower melting point.

The application of furfural for the determination of miscibility solution temperatures of petroleum fractions has been studied. It appears to offer considerable promise over aniline. It is nontoxic and is applicable to a wide range of petroleum fractions. The point of complete miscibility is easily and readily determinable even in darkly colored fractions. It further shows considerable promise as a reagent to eliminate the "mixed aniline point" determination.

Thermal Properties of Hydrocarbons. J. F. FALLON AND K. M. WATSON, *University of Wisconsin, Madison.*

New generalized correlations have been developed for the heat capacities of the ideal vapors, the heat capacities of

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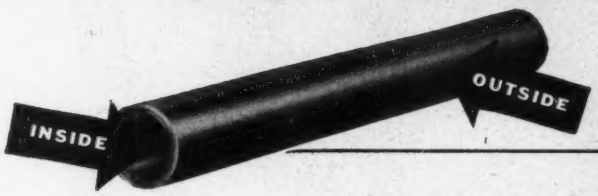

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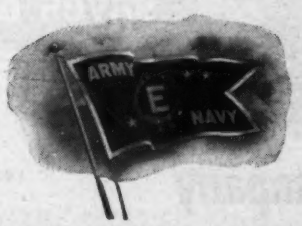


the liquids, and heats of vaporization of hydrocarbons and petroleum fractions. It has been attempted to make these correlations consistent with recently developed heat capacity values for vapors derived from spectroscopic measurements as well as the calorimetrically observed data on petroleum fractions. In addition, it was attempted to make the three correlations thermodynamically consistent with each other.

For the specific heats of the ideal vapors of hydrocarbons containing more than four carbon atoms the following equation is recommended for the range of 0° to 1400° F.:

$C_p = (0.0450K - 0.233) + (0.440 + 0.0177K) \times 10^{-3}t - 0.1530 \times 10^{-6}t^2$ where C_p = specific heat
K = U.O.P. characterization factor
t = temperature ° F.

Equations are presented for the lighter paraffin and olefin gases in two forms:

For temperatures from —300° to +200° F.

$$c_p = 7.95 + u\,T^v$$

For temperatures from 0° to 1400° F.

$$c_p = a + bT + cT^2$$

where c_p = molal heat capacity
T = temperature, ° Rankine

Values for the constants of these two equations are tabulated for paraffins and olefins of four carbon atoms or less.

The specific heats of liquid petroleum fractions are represented by the following equation from 0° F. to a reduced temperature of 0.85.

$C_p = [(0.355 + 0.128 \times 10^{-20°}\text{A.P.I.}) + (0.0503 + 0.177 \times 10^{-30°}\text{A.P.I.}) \times 10^{-3}t]\,[0.05K + 0.41]$

Heats of vaporization at atmospheric pressure were calculated from the Clapeyron equation using the vapor pressure equation of Gamson and Watson. These values are presented as functions of boiling point and molecular weight and A.P.I. gravity in a graphical correlation.

Enthalpies calculated from combinations of these correlations are in good agreement with experimentally observed data on petroleum fractions. The heat capacities are in general somewhat lower and the heats of vaporization higher than those of the general correlation presented by Watson and Nelson [Ind. Eng. Chem., **25**, 880 (1933)]. The new correlations are in better agreement with recent data and more nearly approximate thermodynamic consistency.

Vapor Pressures of Organic Compounds. B. W. GAMSON, *Great Lakes Carbon Corporation, Morton Grove, Ill.*, and K. M. WATSON, *University of Wisconsin, Madison, Wis.*

It has been found that the vapor pressures of all of over forty organic compounds investigated may be represented over wide ranges of temperatures by the following equation:

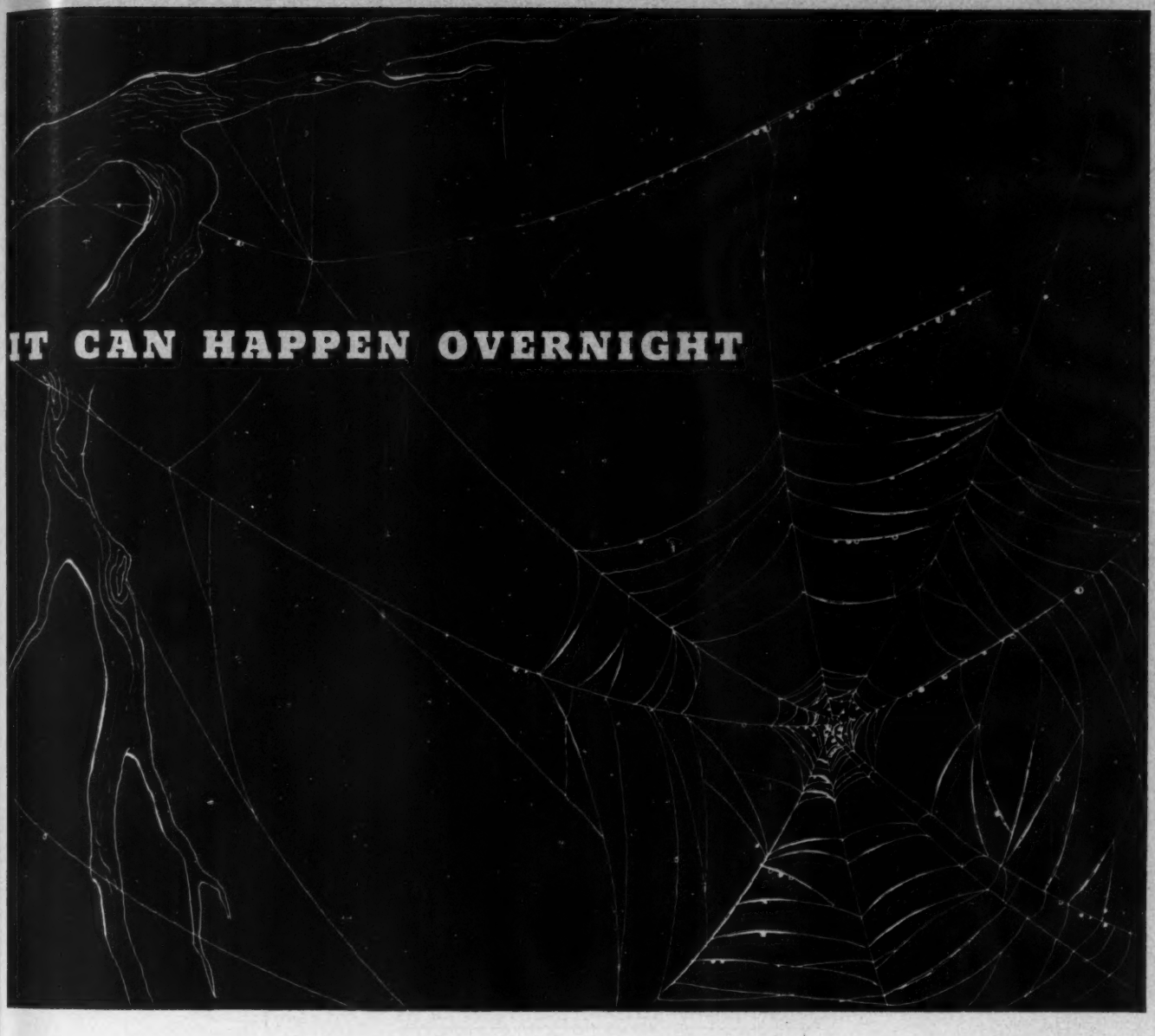
$$\log p = -\frac{A}{T_N} + B - e^{-20(T_N - b)^2}$$

Deviations of experimental data from this equation are generally less than 2 percent for pressures ranging from the critical down to 0.1 mm. of Hg.

The constant b is found to increase progressively as the number of carbon atoms in a homologous series is increased and has been elevated as a function of number of carbon atoms for the paraffins. For other series of compounds.

$$b = b' + \Delta b$$

where b' is the constant of the paraffin of the same number of carbon atoms and



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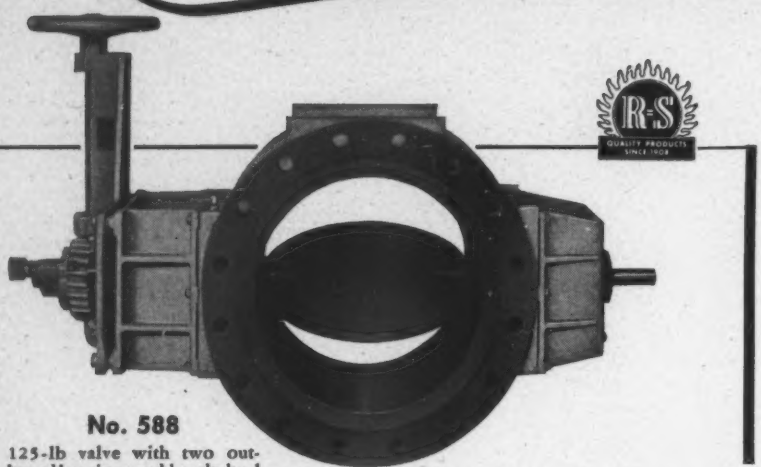

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$$p_c = p'_c + \frac{\Delta p}{n_c + c}$$

where p_c is the critical pressure of a compound containing n_c carbon atoms, p'_c is the critical pressure of the paraffin of the same number of carbon atoms, and Δp and c are constants characteristic of the homologous series. A plot of p'_c as a function of n_c has been developed and the constant Δp and c are evaluated for 14 series of compounds.

By these methods it is possible to estimate a complete vapor pressure curve for any member of the 15 series investigated from a knowledge of only the boiling point.

Junior Chemical Engineers Name Officers in New York

Junior Chemical Engineers of New York have announced the election of officers for the coming year. They include: president, Lieutenant Raymond P. Devoluy, U. S. Navy Materials Laboratory, New York; vice president, Edward T. Maples, the M. W. Kellogg Company; secretary-treasurer, Andrew E. Chute, Foster Wheeler Corporation, and assistant secretary-treasurer, Frank Melaccio, Fratelli Branca & Company.

Among the new committee chairmen elected were Francis B. White, Foster Wheeler Corporation, inter-society activities; Randall D. Sheeline, Picatinny Arsenal, Dover, New Jersey, program; John R. Callahan, publicity, and Edward T. Maples, the M. W. Kellogg Company, banquet.

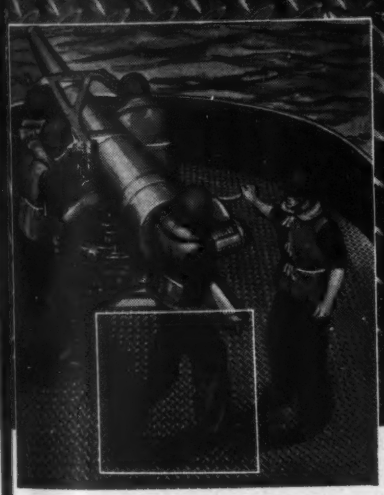
Chemical Exposition to Stress New Processes

Details are being rapidly completed for the forthcoming Nineteenth Exposition of Chemical Industries to be held in Madison Square Garden, New York, beginning December 6.

Charles F. Roth, manager of the exposition, has announced that the display will be comprehensive and well balanced, with better coverage of important major developments than might have been expected, considering prevailing restrictions.

Much of the information to be disclosed reflects either the creation of new industries and their products, or the conversion of existing plants to new uses. Plant conversion is an especially fruitful topic because the conduct of the war involves constant change while the war's end, however far away it may be, will involve sharp competition in the reconversion of hundreds of plants.

Much of the recent progress has been made possible only by advances in the fabrication of highly resistant metals, ceramic linings for pressure vessels, as well as noteworthy innovations in glass and in protective synthetic coatings belonging to the rubber group. Some of the latter are now applied with the spray gun, while kindred products for less severe uses are applied by dipping, spraying or brushing, or are extruded in "worms" and pressed into riveted seams in sheet metal.



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The abstracts here presented are selected from the current literature of science and technology to afford reference to fundamental information not easily available to all readers. Abstracts of articles appearing in readily obtainable trade journals are not included.

Photostat copies of original articles will be supplied at cost by the Leslie Laboratories. Complete or limited bibliographies covering special topics by title, by abstracts, or in complete manuscript, will also be prepared and furnished at reasonable cost by the Laboratories.

Fundamental Physical And Chemical Data

Aliphatic Hydrocarbon Densities, T. G. Stevenin and J. G. Allen, *Ind. & Eng. Chem.* **35** (1943) pp. 788-9.

A simplified correlation of densities of paraffin (and to some extent olefin) hydrocarbons is presented. Based on reduced temperatures and reduced pressures, it gives densities directly without the use of intermediate reduced volumes. Calculated data agree with experimental data within 2 to 5 percent deviation. A previously unpublished correlation by the authors indicated that for liquids a satisfactory plot could be made of reduced temperature, reduced pressure, and reduced volume. A further observation that the critical volumes of paraffin hydrocarbons is approximately constant led to the conclusion that the specific volume can be plotted instead of the reduced volume; or, for more direct use, the reciprocal of specific volume or density can be plotted as one of the coordinates. The chart presented in the article was prepared on this basis. To use the chart it is necessary to know the reduced temperature and reduced pressure of the material in question. The density as pounds per cubic foot can be read directly from the chart.

Phase Equilibria in Hydrocarbon Systems. Composition of Dew-Point Gas in Ethane-Water Eystem, H. H. Reamer, R. H. Olds, B. H. Sage and W. N. Lacey, *Ind. & Eng. Chem.* **35** (1943) pp. 790-93.

An understanding of the role played by water in the phase behavior of hydrocarbon systems is important since this component is nearly always associated with petroleum in underground reservoirs. A background of experimental facts concerning the behavior of gas hydrates at low temperatures has accumulated, but there is a dearth of information at the temperatures encountered in natural reservoirs. Such literature as is available is briefly reviewed. In the experimental work, the influence of pressure and temperature on the composition of the dew-point gas of the ethane-water system was experimentally established. The work covered pressures up to 10,000 pounds per square inch in the temperature interval between 100° and 460°F. Data for other aqueous systems of a similar nature are compared with the values obtained and with predictions based on an assumed thermodynamic behavior for this system. Data are presented in detail in tabular and graphical form, and a bibliography of 14 references is included.

Viscosities of the Methane-Propane System, L. B. Bicher, Jr. and D. L. Katz, *Ind. & Eng. Chem.* **35** (1943) pp. 754-61.

The viscosities of methane, propane, and four of their binary mixtures (20, 40, 60, 80 mole percent methane) were determined with an average error of 3.2 percent at eight pressures (400 to 5000 pounds per square inch) at each of five temperatures (77° to 437°F.) in a rolling-ball inclined-tube viscometer. These data were found to be correlated by the three variables, molecular weight, pseudoreduced temperature, and pseudoreduced pressure, with an average deviation of 2.9 per cent. This correlation can be used to obtain the viscosity of any light paraffin hydrocarbon or hydrocarbon mixture with an average error of about 3.5 per cent. The apparatus used is described in some detail, as well as the method of using it to secure the data. The data are presented in considerable detail in graphical and tabular form.

The Viscosity Function. IV. Non-ideal Systems, E. P. Irany, *Jour. Am. Chem. Soc.* **65** (1943) pp. 1392-8.

The interpretation of viscosity data in terms of the state of liquids and of the interaction of substances in the liquid phase is based on various arbitrary premises inherent in the customary methods of graphical analysis. The basic problem—the correct formulation of the additive function of viscosity in mixtures—is still inaccessible by purely speculative approach. Because of the prevailing confusion in the methods of evaluation, and the large number of recorded observations on association, dissociation, compound formation, etc., that are wrong, the whole field is in need of critical revision. Analysis of viscosity data by means of the functional scales developed in the preceding papers by the author continues to prove its reliability as shown in application to a selection of non-ideal systems. In the present article the system sulfuric acid-ether, the aqueous and formamide mixtures of dioxane, the lower alcohols and fatty acids, were discussed as examples. The method not only yields more plausible and concordant results than are otherwise obtainable but it reveals fine distinctions which, in the commonly adopted practices of evaluation, are entirely lost.

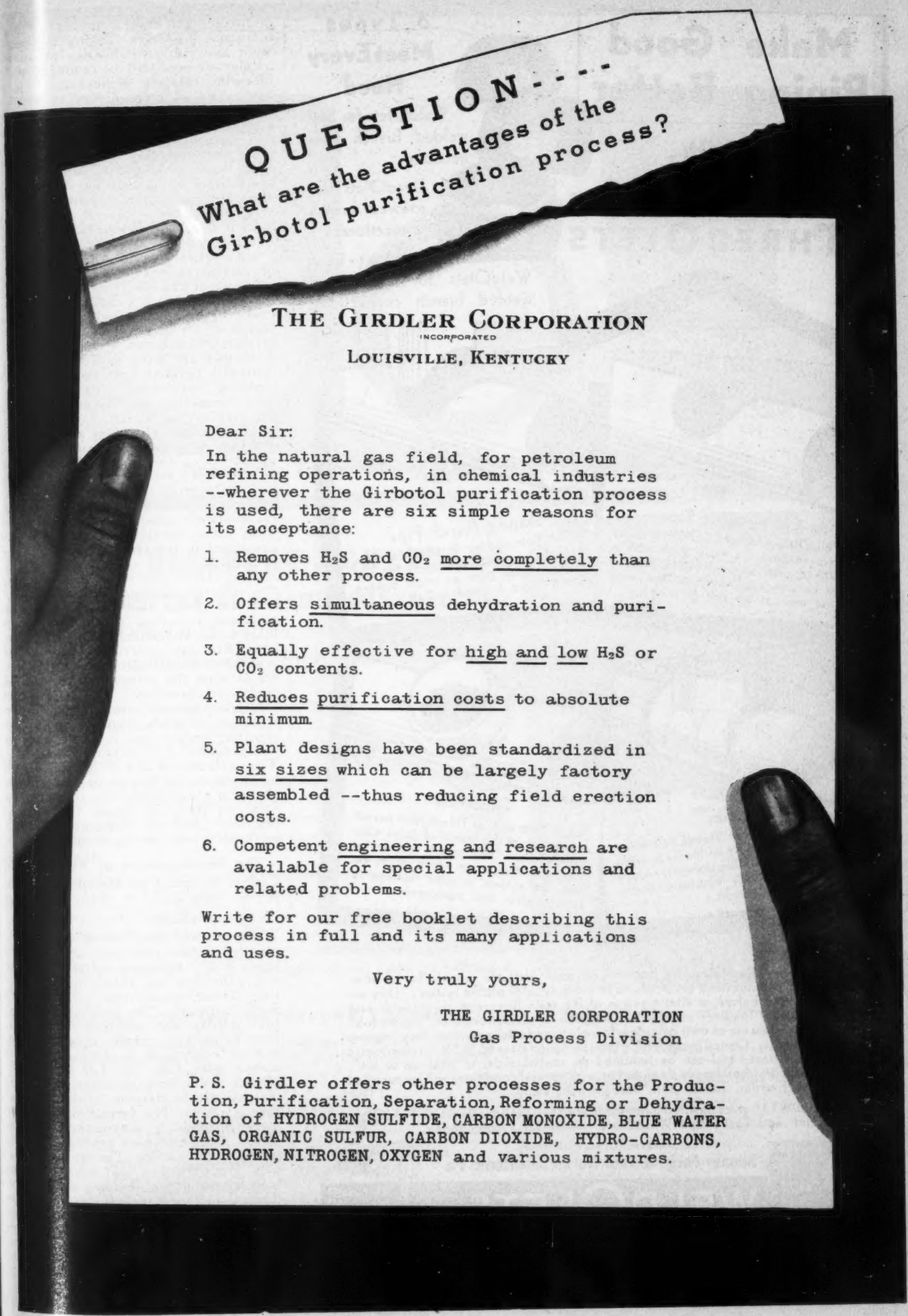
Solvent Properties of C_8 Aromatic Hydrocarbons, P. D. Hammond and E. H. McArdle, *Ind. & Eng. Chem.* **35** (1943) pp. 809-10.

Domestic coal tar light oil sources provide annually a total of 10 to 15 million gallons of mixed xylenes and C_8 aromatics in the form of close boiling cuts and naphthas. Twice as much toluene and ten times as much benzene have come from these same sources. It is not surprising that, except for benzene and toluene, no highly purified aromatic hydrocarbon has been obtainable until recently at low cost and in tank car quantities. In the future the balance of the supply may be shifted. While coking in ovens favors the formation of benzene, several petroleum conversion processes result in a preponderance of the higher aromatics. Data are presented in the article on the solvent properties of the xylenes. The data are presented in tabular form and give a comparison of the physical properties of the material used, solvency properties, and viscosities of certain solutions. o-Xylene has a 4-20 percent superiority over the meta and para isomers in ability to dissolve one natural resin and one synthetic resin. Solutions made with the higher-solvency o-xylene are, with one exception, 8 to 75 per cent more viscous than the corresponding meta and para solutions. Thus o-xylene is a doubly desirable solvent.

Chemical Compositions And Reactions

Concept of Catalytic Chemistry, A. V. Grosse, *Ind. & Eng. Chem.* **35** (1943) pp. 762-7.

Within the last decade a large number of new catalytic reactions have been



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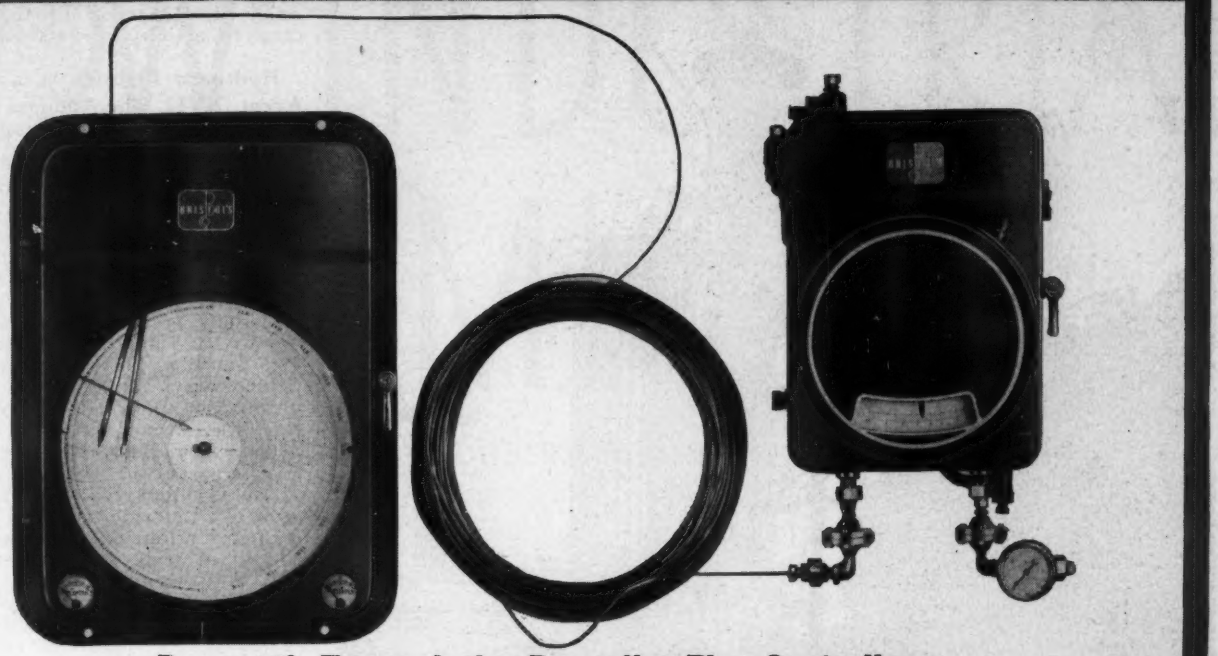
discovered and developed into important industrial processes. Taking the petroleum and rubber industries as an example, one need only be reminded of the following catalytic achievements: polymerization of mono-olefins to aviation gasoline, of diolefins to Buna rubber, of acetylene to vinylacetylene and further to neoprene; dehydrogenation of low-molecular paraffins to corresponding mono- and diolefins, of naphthenes to aromatics, of ethylbenzene to styrene; cyclization of paraffins, olefins, or acetylenes containing a row of six or more carbon atoms to aromatics such as toluene; alkylation of paraffins with olefins to higher paraffins; hydrogenation of carbon monoxide to hydrocarbons, cracking of gas oils to aviation and motor gasoline, and condensation of alcohol to butadiene. The author states that it is safe to say that, for every new noncatalytic reaction, at least three catalytic ones are being discovered and industrially developed. In contrast to this amazing development in the applied field, theoretical and scientific concepts are lagging far behind. Fundamentally, when chemical substances are associated and one or more of them react, two possibilities should be distinguished: In the first case one or several chemical substances react without interference or influence from the other chemical substances present. In the second case these other substances, which are not consumed in the reaction, influence the chemical behavior of the reacting substances. They may increase or decrease the velocity of the reaction and they may also change its direction. Obviously, reactions according to the first possibility form the content of classical chemistry. Reactions according to the second possibility should form the subject matter of what the author proposes to call "catalytic chemistry." The objective of catalytic chemistry is to collect, systematize, correlate, explain, and, where possible, predict the catalytic behavior of inorganic and organic substances. The explanations and predictions should be based on the known or determinable chemical properties of the reactants and catalysts involved, under the physical reaction conditions. Various deductions are made from these basic viewpoints.

The Decomposition of Ethylene and Carbon Monoxide on Metallic Catalysts, A. R. McKinney, *J. Phys. Chem.* 47 (1943) pp. 152-63.

The metals iron, cobalt and nickel rapidly decompose carbon monoxide above 250°C. Osmium, platinum, copper and palladium are comparatively inactive. Those metals that are active all form carbonyls. The order of decreasing activity for ethylene decomposition by nickel, cobalt, iron and copper is compared to their respective atomic radii, 1.24, 1.25, 1.27 and 1.28 A. Nickel and cobalt decompose ethylene increasingly to methane as the temperature is raised. The formation of ethane goes through a maximum at about 280°C. Copper causes production of no methane up to 460°c. The reaction products are hydrogen and ethane. When iron is used large amounts of both hydrogen and methane are formed. From an equimolar mixture of ethylene and carbon monoxide the decomposition of ethylene reaches 90% at 10° to 60° lower temperature than without carbon monoxide. The relative yields of hydrogen, ethylene, and methane are influenced to a considerable extent by carbon mon-



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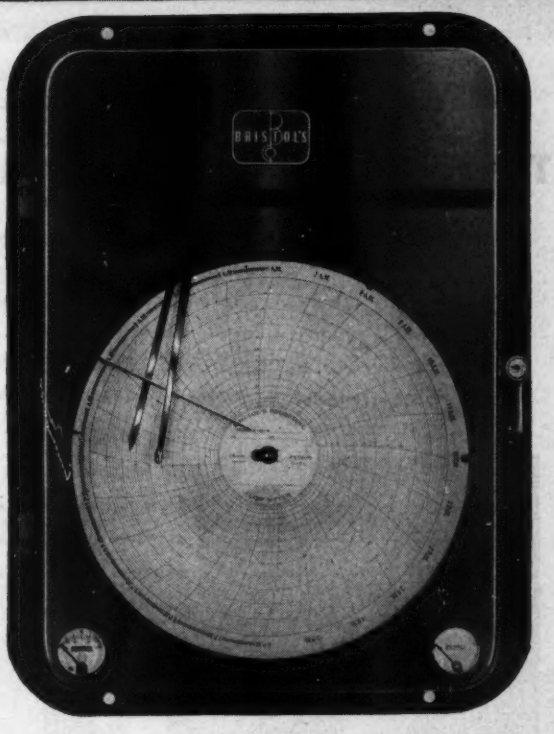

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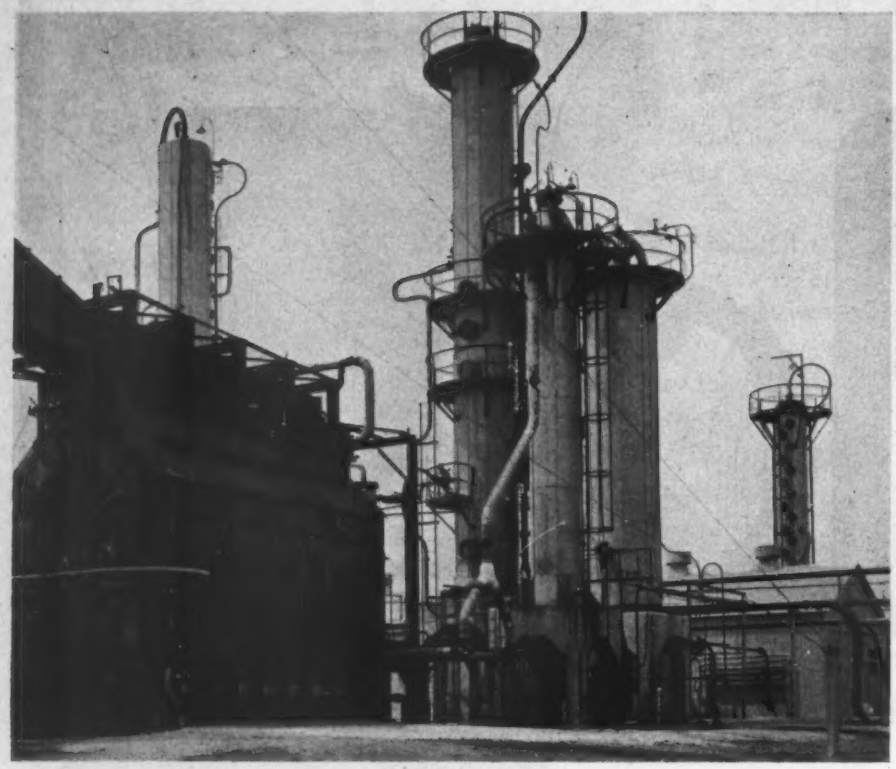

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oxide. Evidence as to the source of catalytic activity is reviewed.

Hydrogen Fluoride as a Condensing Agent. XVII. The Addition of an Alkyl Chloride to the Double Bond, J. H. SIMONS AND A. C. MEUNIER, *Jour. Am. Chem. Soc.* **65** (1943) pp. 1269-71.

As a continuation of an investigation of the catalytic activity of hydrogen fluoride, the authors studied the reactions of an alkyl chloride with olefins. Hydrocarbons, phenols, alcohols, and acids have previously been added to olefins by the catalytic influence of hydrogen fluoride. This investigation shows that an alkyl halide can be added to an unsubstituted olefin. Tertiary butyl chloride was found to react with cyclohexene in hydrogen fluoride to produce a 65% yield of cyclohexyl chloride, 11.5% cyclohexyl fluoride and an 11% yield of a chloride identified as 1-chloro-3-t-butylcyclohexane. Reactions of t-butyl chloride with trimethylethylene and of isopropyl chloride with cyclohexene produced no isolable addition product of the chloride to the olefin.

Hydrogen Fluoride as a Condensing Agent. XVIII. Aralkyl Ketones, J. H. SIMONS AND E. O. RAMBLER, *Jour. Am. Chem. Soc.* **65** (1943) pp. 1390-92.

The paper is a further study of the effect of hydrogen fluoride as a condensing agent. Aromatic ketones were found to condense with themselves in the presence of hydrogen fluoride. Those containing two or three hydrogen atoms on the carbon atom adjacent to the carbonyl group gave benzoic acid and a resin as by-products. At a lower temperature dypnone was formed from acetophene and 1, 3-diphenyl-2-methylpentane-2-one-1 from propiophenone. a-Methylstyrene and 3-phenylpentene-2 were obtained, respectively, from the resins from acetophenone and propiophenone. Isobutyrophenone gave a resin but no benzoic acid, and benzophenone and a-trichloroacetophenone gave no reaction. It is postulated that the condensation proceeds to form first a tertiary alcohol. Only ketones with one or more alpha hydrogen atoms can do this. This tertiary alcohol can polymerize. It can also dehydrate to form an unsaturated ketone, if there are two or three alpha hydrogen atoms in the original ketone. This unsaturated ketone can either polymerize or react with hydrogen fluoride to form benzoyl fluoride and a substituted styrene polymer

The Addition of Hydrogen Fluoride to Halo-olefins, A. L. HENNE AND E. P. PLUEDDEMAN, *Jour. Am. Chem. Soc.* **65** (1943) pp. 1271-2.

Previously reported cases of the addition of hydrogen fluoride to the halogenated olefins are supported by more examples and an extended generalized study. The technique outlined in three previous papers was used, with minor adjustments. Large quantities of material were prepared, making possible the purification and identification through physical properties of all the compounds. Monohalo-olefins of the type RHC=CHX did not react well and did not yield clean cut products. In contrast an olefin $(CH_3)_2C=CHCl$ was found to react very readily with hydrogen fluoride at 0° and also at —23° to yield 65% of the hydrogen fluoride addi-

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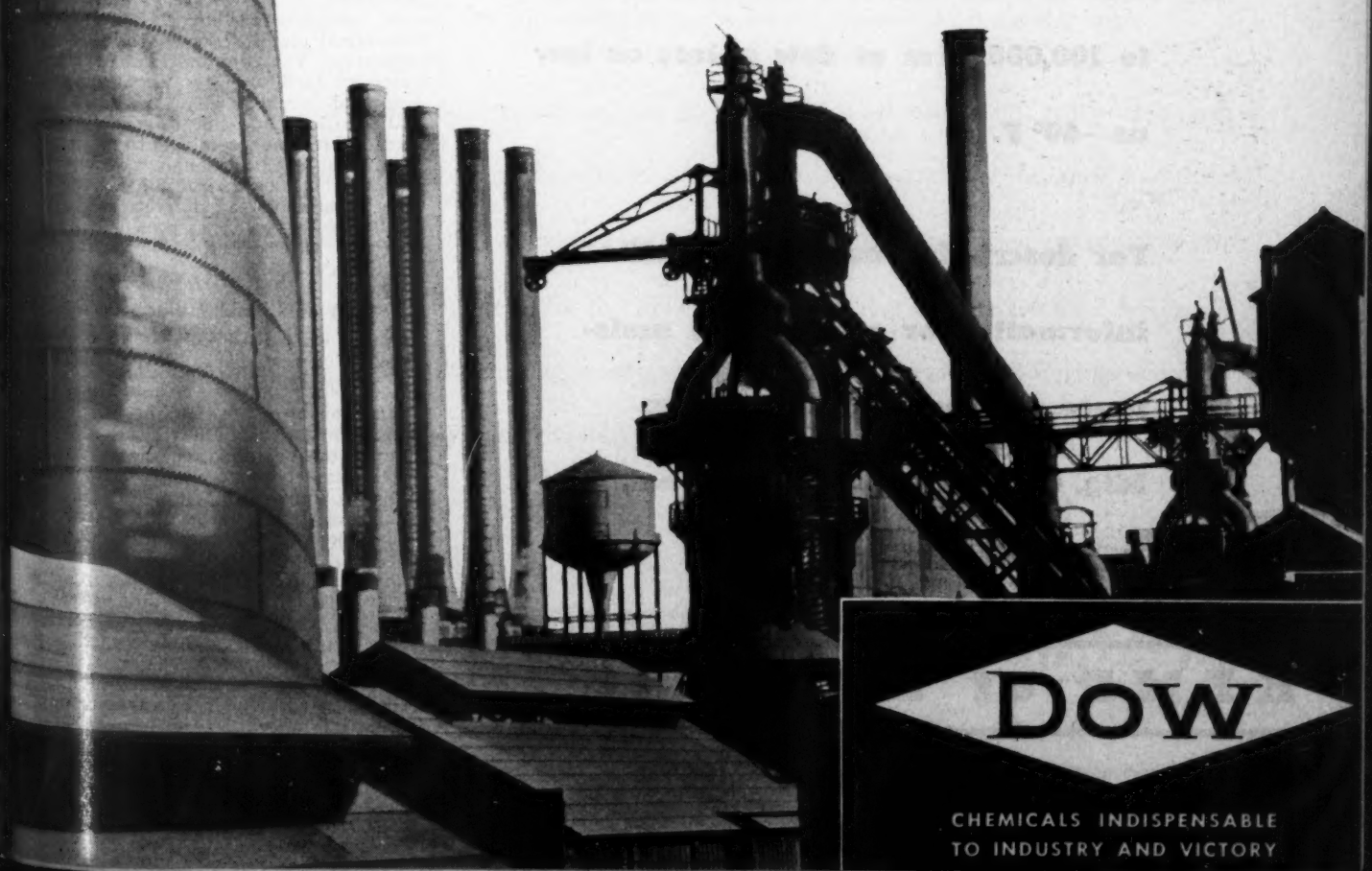

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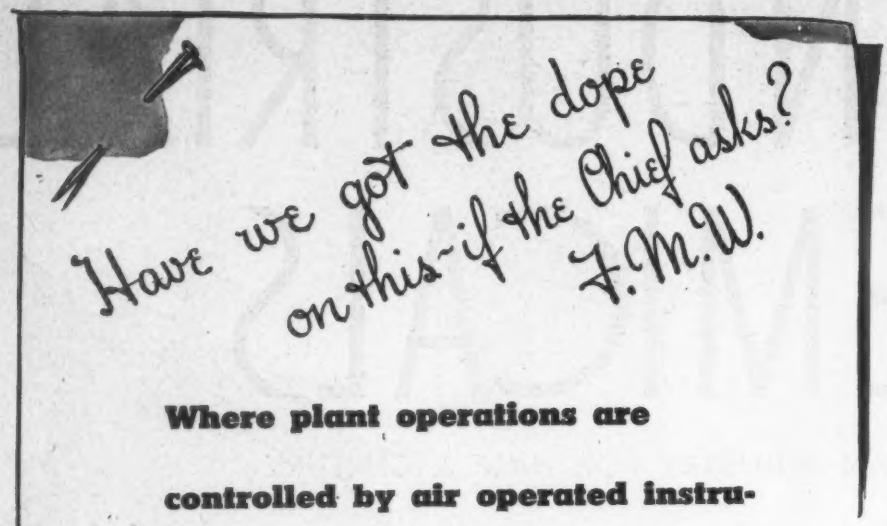

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tion compound. Tar formation was negligible at the lower temperatures, but increased rapidly at higher temperatures. The same chlorofluorobutane was obtained almost as readily from methylallyl chloride. Monohalo-olefins of the type $RCX{=}CR'R''$ reacted extremely readily with hydrogen fluoride to give mixtures of difluorides and dichlorides in preference to the straight addition product. Asymmetrical dihalo-olefins of the type $RR'C{=}CX_2$ combined smoothly with hydrogen fluoride, preferably at about 65°, and without much substitution. The addition of hydrogen fluoride to symmetrical dihalo-olefins $RCX{=}CXR'$ gave contradictory results. Trichloroethylene, $CHCl{=}CCl_2$ and its homolog $CH_3CCl{=}CCl_2$ did not combine with hydrogen fluoride even at 160°, and the original olefins were recovered unchanged. Perchloro-olefins and hydrogen fluoride do not add.

Manufacture: Process And Plant

Some Considerations in the Design of Thick-Wall Pressure Cylinders, C. W. COMSTOCK, *Trans. Am. Inst. Chem. Engrs.* **39** (1943) pp. 299-318.

The paper is a critical reexamination of the assumptions underlying the mechanical design of cylindrical reaction vessels, with a discussion of the several theories of rupture and their effects on proportions of the structure. Its purpose is to emphasize the origin and limitations of the usual formulas and to caution against the blind acceptance of numerical results.

Fractional Distillation of Binary Mixtures. Number of Theoretical Plates and Transfer Units, A. J. V. UNDERWOOD, *Jour. Inst. Petr.* **29** (1943) pp. 147-56.

The author shows that for binary mixtures with constant relative volatility, the number of transfer units can be calculated in a form that readily permits comparison with the number of theoretical plates required for the same separation. The computation can in both cases be facilitated by using a simple graphical procedure. Any separation with finite reflux can be exactly converted into an equivalent separation with total reflux by using a modified relative volatility and modified compositions. Mathematical derivations of the equations are given in considerable detail and the graphical construction illustrated.

Studies of Liquid Holdup in Packed Towers, B. W. JESSER AND J. C. ELGIN, *Trans. Am. Inst. Chem. Engrs.* **39** (1943) pp. 277-98.

The authors state that the purpose of their work was to make a systematic comprehensive, and accurate study of holdup as related to the operating variables of liquor velocity and physical properties. The data presented deal only with operating holdup and not with static holdup; the latter is the quantity of fluid required to wet the packing. The tower used in the work was constructed of glass, 6 inches in diameter x 50.5 inches high. The packings used were ½inch, ¾-inch, and 1-inch glass spheres, ¼-inch, ½-inch and 1-inch Berl saddles, and ½-inch carbon rings. Liquid holdup with no gas flow was de-

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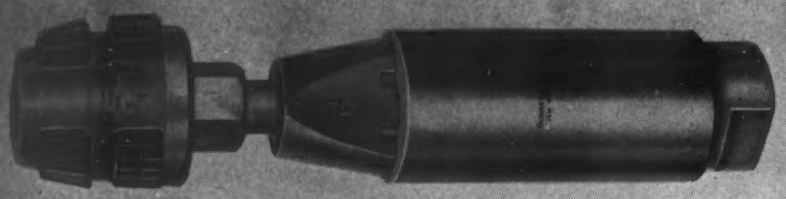

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termined for three different types and sizes of packings over the entire range of liquid flow using four different liquids. Formulae are given that enable one to predict, without experimental work, the holdup of any liquid on most of the common types of packing. A mechanism for the flow of liquid through a packed tower is proposed. It was found that holdup is an exponential function of liquor velocity and this exponent is essentially the same for any one type of packing, irrespective of size. The change in holdup with variation in specific surface tension, specific gravity and relative viscosity of the liquid is an exponential function. This exponential function is the same for all types of packing and, for the cases of specific gravity and relative viscosity, it is independent of liquor velocity.

Overall Plate Efficiency of Commercial Hydrocarbon Fractionating Columns as a Function of Viscosity, H. G. DRICKAMER AND J. R. BRADFORD, *Trans. Am. Inst. Chem. Engrs* **39** (1943) pp. 319-60.

The plate efficiency of fractionating columns is a function of tray design, column load, temperature and pressure of operation, and physical properties of the material being fractionated. For any group of columns having similar tray design and operated near maximum capacity, the overall tray efficiency is primarily a function of the physical properties of the material fractionated at the column temperature and pressure. The correlation between viscosity and plate efficiency has been developed from test data on 54 refinery fractionating columns. The curve was checked from data on 30 commercial columns obtained from the literature. The effect of variations in tray design was considered. Curves are given showing the relationship of tray efficiency and molal average viscosity in centipoises. The curves are straight lines on semi-logarithmic paper.

Liquid Extraction in Perforated-Plate and Packed Towers, J. ALLERTON, B. O. STROM AND R. E. TREYBAL, *Trans. Am. Inst. Chem. Engrs.* **39** (1943) pp. 361-84.

A study was made of the extraction rates, hold-up, and possible through-puts in the extraction of benzoic acid from toluene and kerosene in a perforated-plate tower and from kerosene in a tower packed with half-inch carbon rings. Through-puts in the perforated-plate tower, when compared with those found in the literature for other towers are shown to be the best as yet obtained, with the exception of spray towers. The extraction rates for kerosene with perforated plates were found to be superior to those obtained in the packed tower, while in the case of toluene they may or may not be better depending upon the design of the plates. By sampling the liquids above and below each plate, an operating line, showing the change in concentration of benzoic acid throughout the column, was established. The plate tower used comprised 11 plates spaced 4-¾ inches apart perforated with 3/16-inch holes with 51 holes on a plate of 3.63 inches in diameter. The authors consider that the perforated-plate tower has been shown to be superior to all apparatus for which there are data, with the exception of one unpacked spray

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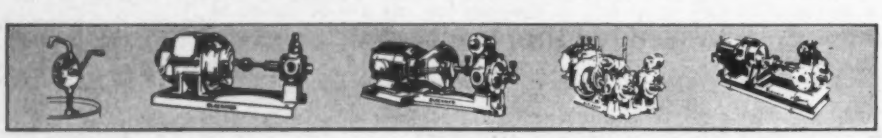

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tower. The data are presented in considerable detail in tabular and graphical form.

Recent Developments in Welding, C. W. Brett, *Jour. Inst. Petr.* **29** (1943) pp. 157-62.

Developments in the field of welding have been of the greatest importance during the war period. Until quite recently it was considered that only identical materials could be welded. Not long ago a process was perfected which made it possible to weld almost any combination of metals. For example, aluminum can be welded to steel so effectively that the weaker parent metal will fail before the weld. Many types of work that can be accomplished through welding are briefly discussed and many typical repair jobs.

Fluid Catalyst Process, E. V. Murphree, C. L. Brown, H. G. M. Fischer, E. J. Gohr, and W. J. Sweeney, *Ind. & Eng. Chem* **35** (1943) pp. 768-73.

When oils are cracked, carbon is deposited on the catalyst, reduces its activity, and makes necessary its removal by burning with air. In the Fluid Catalyst cracking process the catalyst is handled as a fine powder and is kept in a fluidized condition so that it can be handled substantially as a liquid. The catalyst is conveyed through the reactor by the oil vapor and is separated in dust recovery equipment; then the product vapor flows to distillation apparatus. The carbonized catalyst flows down a standpipe in a high-density condition. Its pressure is thus increased sufficiently to permit injection into a stream of air, which carries it to the regenerator where the carbon is burned. The catalyst is separated, the flue gas is vented to the atmosphere, and the regenerated catalyst passes down a second standpipe and is injected into the oil vapor going to the reactor. The process is thus completely continuous as regards oil, air, and catalyst flow. Information is available on production of motor gasoline from a variety of charge stocks. The gasoline has a clear octane number of 92-94 by the CFR Research method. Operating conditions can be adjusted to produce high-octane aviation fuel, butylenes, and toluene. Gasoline fractions from the operation can be used directly as aviation base or can be reprocessed in the fluid catalyst unit or hydrogenated. Aviation fuels produced by these methods have low alkylate requirements, and after addition of tetraethyllead, they meet the highest specifications.

Isothermal and Adiabatic Flow of Compressible Fluids, C. E. Lapple, *Trans. Am. Inst. Chem. Engrs.* **39** (1943) pp. 385-432.

In pipe lines handling compressible fluids at high pressure drops the flow conditions are usually intermediate between isothermal and adiabatic, depending upon the flow rate, the degree of pipe insulation, and the length of the pipe. A graphical presentation is given by the authors to afford a direct quantitative comparison of the effect of adiabatic and isothermal flow conditions on mass discharge rates through such pipe lines. It is shown that the mass discharge rate through a given pipe line at a specified pressure drop for adiabatic flow conditions is, in general, greater

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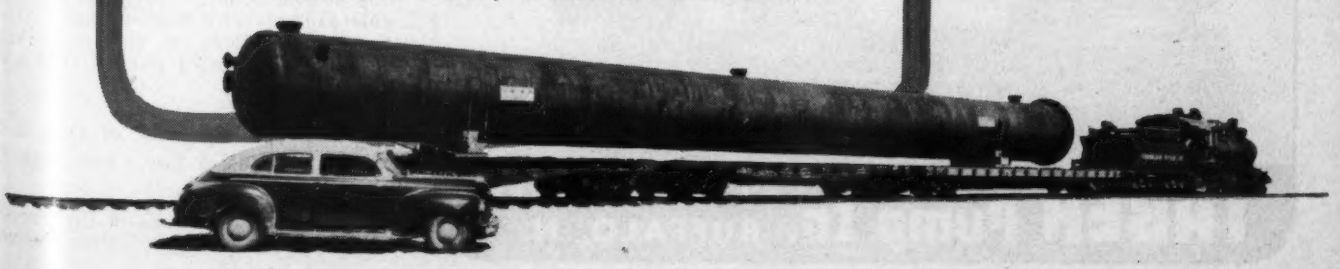

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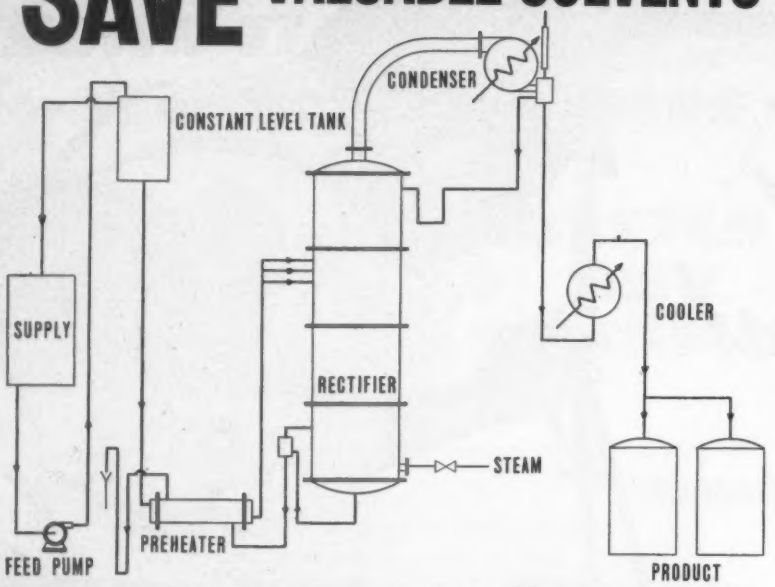

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than for isothermal flow conditions but never more than 20 percent greater than for isothermal flow conditions and practically the same as for isothermal flow conditions for pipes more than 1000 pipe diameters long. The adiabatic flow equations will reduce, as is necessary, to the corresponding isothermal flow equations if the value of k (ratio of specific heats), appearing in the adiabatic flow equations, is set equal to unity. Design charts were prepared for various values of k, and comparisons of the theoretical curves with available literature data show excellent agreement. Complete derivations of equations and illustrations of application are presented in the Appendix to the article.

Prevention of Butadiene-Air Explosions by Addition of Nitrogen and Carbon Dioxide, G. W. JONES AND R. E. KENNEDY, *U. S. Bur. Mines, Rept. Investigations* 3691 (1943) 11 pages.

The lower limit of inflammability of butadiene in air is 2.00 percent and the upper limit 11.50 percent. To make all mixtures of butadiene with air non-inflammable requires the addition of at least 19.6 volumes of nitrogen or 12.1 volumes of carbon dioxide. Added nitrogen or carbon dioxide has little effect on the lower limit of inflammability, but the upper limit is reduced practically in direct proportion to the amount of inert gases added. A tabulation is given showing the volumes of nitrogen and carbon dioxide required to render various combustibles non-inflammable. The ratio of carbon dioxide to nitrogen required is varied between 0.53 and 0.62 with an average of 0.57.

Products: Properties And Utilization

Unsaturation of Butadiene and Related Polymers, A. R. KEMP AND H. PETERS, *Ind. & Eng. Chem., Anal. Ed.* 15 (1943) pp. 453-59.

The paper describes procedures developed to determine the unsaturation of various butadiene and related polymers and copolymers, as well as mixed vulcanizates of Buna S and rubber. These methods are based on the use of p-dichlorobenzene as a solvent and iodine chloride as the addition agent, following the general technique employed in the standard Kemp-Wijs method for the determination of the unsaturation of natural rubber. The ratio of butadiene to styrene in copolymers has been calculated from the iodine value and from the carbon-hydrogen ratio. However, the accuracy of these procedures is subject to several variables that are discussed. Unsaturation data are presented on highly purified emulsion-type polymers of butadiene-isoprene and butadiene-styrene types that agree closely with the presence of one double bond for each diolefin molecule present. The reaction rate of Buna S with halogens is shown to agree closely with that of natural rubber hydrocarbon.

Thixotropic Behavior of Oils, R. N. WELTMANN, *Ind. & Eng. Chem., Anal. Ed.* 15 (1943) pp. 424-9.

Various types of oils in the viscosity range of 1 to 800 poises were measured

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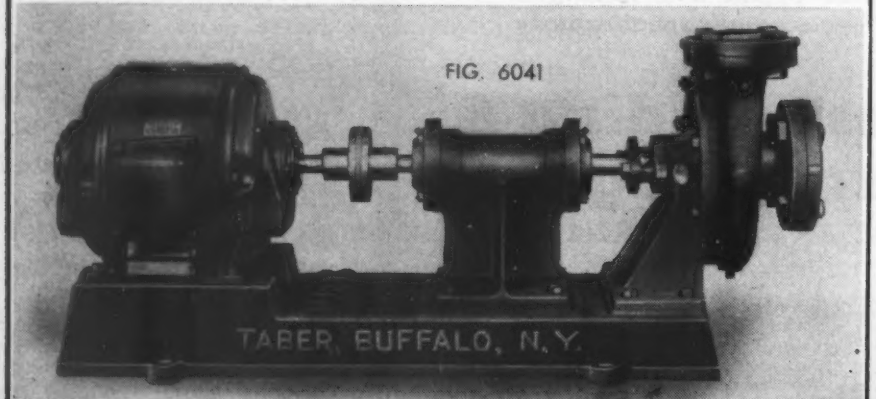

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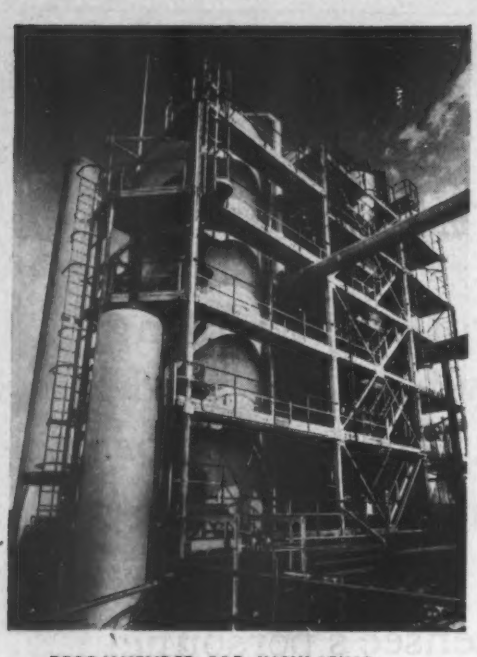

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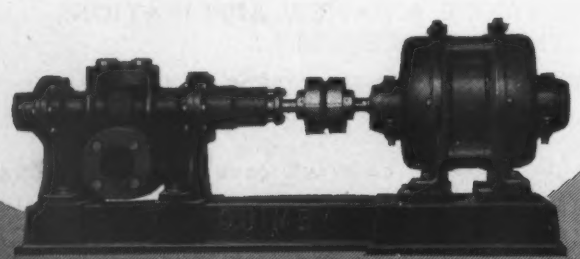

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on a rotational viscometer capable of imparting shearing stresses over a wide range. From these oils, flow curves were obtained extending from low to high rates of shear. All these oils showed a definite thixotropic behavior and exhibited all the characteristics of thixotropic plastics above a certain rate of shear designated as "the limiting rate of shear." Below this critical point the oils behaved like true Newtonian liquids, showing no signs of thixotropic structure. The limiting rates of shear were found to be related to the measured true Newtonian viscosities of the oils. The product of limiting rate of shear and viscosity was a constant for all the oils tested. It is pointed out in the article that if standard oils are used to calibrate viscometers they must be used at rates of shear less than the critical, i.e., in the range in which the oil behaves as a true Newtonian liquid.

Analysis of Butane-Isobutane Mixture, A. W. FRANCIS, *Ind. & Eng. Chem., Anal. Ed.* **15** (1943) pp. 447-8.

Butane-isobutane mixtures are analyzed by fractional distillation at low temperature, but to secure accurate results this requires a trained technique, at least 3 hours' time, and at least a 10 gram sample, all of which are disadvantages. The method described by the author depends upon the observation of the critical solution temperature of the butane mixture with pure o-nitrotoluene. The apparatus and procedure are described. The temperature is judged by the appearance or disappearance of cloudiness that can be observed within 0.1° or 0.2° C., corresponding to less than 1 percent error in percentage of isobutane. The test requires 10 to 15 minutes. The composition of the butane mixture is a linear function of the critical solution temperature. The method is intended for the analysis of a wholly butane mixture. Olefins must be absent, for a small percentage will lower the critical solution temperature considerably. The presence of 1 percent propane in the butane mixture would cause an error of about 2.6 percent in isobutane. One percent of isopentane would make the percentage of isobutane only 0.2 percent too low. The effect of other contaminants is briefly discussed.

RARE CHEMICALS

The National Registry of Rare Chemicals, Armour Research Foundation, 33rd, Federal and Dearborn Streets, Chicago, Illinois, has received urgent requests for the chemicals listed below. If anyone has one or more, even if only in one-gram quantities, please inform the Registry.

1. **N-Ethyltetrahydro derivative of 8-hydroxyquinoline**
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6. **1-3 Pentadiene**
7. **Ethyl Allene**
8. **1-3-Cyclohexadiene**
9. **1-4 Cyclohexadiene**
10. **2-Chloro Pentane**
11. **4: 4' Diamidino diphenoxy propane**
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☆ BUSINESS NOTES ☆

P. S. Jones Becomes Sales Manager for Cutler-Hammer

P. S. Jones has been appointed general sales manager for Cutler-Hammer, with headquarters in Milwaukee, Wisconsin. He first became associated with the company as sales engineer, in 1915. Four years later he was transferred to the Pittsburgh office and was later appointed branch manager of sales territory in that area. For the past 14 years prior to his new appointment, he has been in charge of sales in the New York territory. He will now have direct supervision of sales for the company through its 30 selling districts throughout the country.

P. S. Jones

Brown Instrument Engineer Takes on More Duties

Gavin S. Younkin, who has been liaison engineer for Brown Instrument division of the Minneapolis-Honeywell Regulator Company with its customers in the petroleum and chemical industry on the West Coast, has taken on additional duties as manager of the Los Angeles district office of the San Francisco branch.

L. E. Hammer Joins Worthington Pump

L. E. Hammer has been appointed assistant works manager of the Moore Steam Turbine Division, Wellsville, New York, of Worthington Pump and Machinery Corporation. His experience has been chiefly in the field of steam-turbine manufacture since his graduation from the University of Pittsburgh in 1923.

Everlasting Valve Company Promotes Cecil Davey

Cecil Davey has been named vice president and general manager for Everlasting Valve Company, Jersey City, New Jersey. His connection with the company began in 1911, and he has held various positions in the organization since that time.

Shoemaker Heads Dow Eastern Sales Office

Clayton S. Schoemaker has been appointed Eastern sales manager for The Dow Chemical Company, with headquarters at 30 Rockefeller Plaza, New York. He had been associated with the company for a number of years and has occupied various sales executive positions.

Frederick A. Koch has been named assistant Eastern sales manager. He has been assistant manager of the New York sales office for 15 years. He will continue to have headquarters in New York.

C. S. Shoemaker

F. A. Koch

Monsanto Chemical Company To Increase Facilities

Construction of additional manufacturing facilities for Resinox phenolic resins and molding compounds at Monsanto Chemical Company's plastics plant at Springfield, Massachusetts, has been approved by the War Production Board. The new facilities have been made necessary by an increased demand for high impact phenolic plastics compounds in war applications.

Dietz Export Manager For Allis-Chalmers

Paul Dietz has been appointed export sales manager for the general machinery division of Allis - Chalmers Manufacturing Company, with headquarters in Milwaukee, Wisconsin.

Paul Dietz

Dietz comes to Allis-Chalmers from the export division of the B. F. Goodrich Company, Akron, Ohio. During the 15 years he was with Goodrich, Dietz was stationed in Mexico, China and French Indo-China. He was in Hong Kong when it fell to the Japanetse, returning to this country following negotiations betweten the state department and the Japanese government.

He was born in Brazil. Following his graduation from Miami University at

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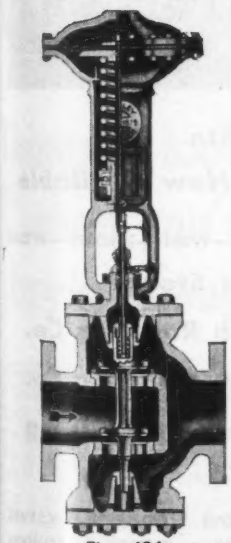

Fig. 484

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Oxford, Ohio, he spent a year at the Frederick Willhelm University in Breslau, Germany, as an exchange scholar for the Institute of International Education of the Carnegie Foundation.

Joining Goodrich in 1927 he went to Mexico as their manager in 1930. In 1932 he went to China, and after the fall of France in 1939, he also went to French Indo-China.

Wilson Technical Director For Arthur G. McKee

Dustin W. Wilson has been appointed technical director of the petroleum refining division of Arthur G. McKee & Company, Cleveland, Ohio.

During the past few years, Wilson has served as technical consultant of the refining division of the Petroleum Administration for War, in which capacity he had an important part in helping PAW develop a war program for the petroleum refining industry. He has been an active chemical engineer for 26 years. He was educated at the University of Maine and at the Massachusetts Institute of Technology where he received a B.S. degree in Chemistry in 1917.

For ten years prior to joining PAW, he was associated with The M. W. Kellogg Company as a chemical engineer and a sales, engineering and designing executive. He was also a director of the company.

Other positions held by Wilson include those as chemist for the United States Bureau of Mines and the Chemical Warfare Service in World War I; chemist for National Carbon Company; assistant professor of chemical engineering at M.I.T.; chemical engineer for Iroquois Gas Corporation; and vice president of Dry Quenching Equipment Corporation of New York.

Belchetz to Research For Stauffer Chemical Company

Stauffer Chemical Company announces appointment of Dr. Arnold Belchetz as director of research and development. He has been associated with the Shell group and The M. W. Kellogg Company for the past 15 years. He is a graduate of Emmanual College, Cambridge University, England.

Tulsa Chemical Company Formed To Produce Hydrofluoric Acid

Tulsa Chemical Company, Tulsa, has been organized for the manufacture of anhydrous hydrofluoric acid. Interest in the company is divided among Pennsylvania Salt Manufacturing Company, Philadelphia, Mahoning Mining Company, Rosiclare, Illinois, and Ozark Chemical Company, Tulsa. Officers of the company are George B. Beitzel, president; C. O. Anderson, vice president; L. A. Smith, treasurer; C. M. Bush, assistant treasurer; and S. H. Davis, secretary.

An anhydrous hydrofluoric acid plant is being erected at Tulsa, and production is expected to begin during October.

Quigley Company Appoints New Southwest Distributors

Quigley Company, 56 West 45th. Street, New York, announces the appointment of Steve C. Maples and Company, 1120 S. Florence Street, Tulsa, and 112 E. Brown Street, Pampa, Texas, as distributors of Quigley pro-

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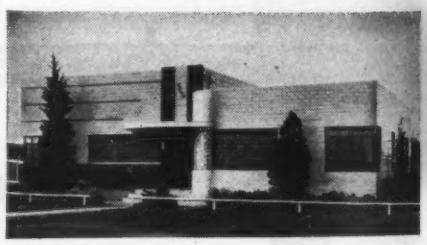

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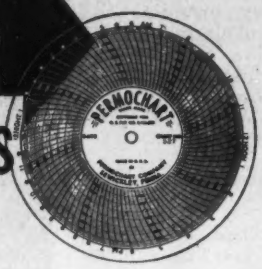

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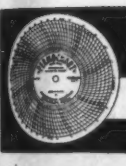

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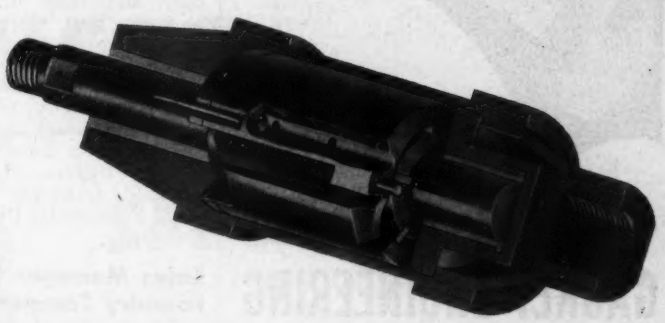

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This Airetool power seal permits the use of heavier cutter head combinations to combat severe deposits. Motor will not stall even when loaded down to 50 R.P.M. Picks up quickly when power is applied.

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ducts, with complete stocks for immediate shipment. Quigley products include refractory and insulating materials for the construction and maintenance of all types of industrial furnaces, acid proof cements, joint sealing compounds, cleaning compounds and protective coatings.

Strong, Carlisle Announces Personnel Changes

The Strong, Carlisle and Hammond Company, Cleveland, Ohio, announces the following changes in personnel:

R. L. Clark has been appointed manager of the steam specialties department. He succeeded R. L. Keech, who is now devoting all of his time to the manufacturing division. Clark has been with the company for nearly 25 years, serving in various capacities in the factory and sales department as service and erecting engineer, sales engineer, and more recently as assistant manager in charge of sales promotion and advertising.

L. H. Boleky, 634 Wabash Building, Pittsburgh, will represent Strong steam specialties in Eastern Pennsylvania and West Virginia. He is replacing Fred Fernald, deceased. Boleky formerly was with Pittsburgh Piping and Equipment Company.

Sales Manager for Ohio Steel Foundry Company Dies

Charles E. Malley, sales manager of the Springfield Plant of The Ohio Steel Foundry Company, died at his home, July 11. He had been with the company since 1924 and was sales manager at Springfield for the last seven years, and was a specialist on the engineering, application and sales of heat and corrosion-resisting alloy castings.

Government Terminals in Florida in Operation

General American Transportation Corporation, announces that the Division of General American Tank Storage Terminals will operate two government-owned terminals in Florida.

These terminals which are located at Jacksonville and Panama City are not yet quite completed—nevertheless, they are already in partial operation.

Oil will be hauled from Gulf refineries to the terminal at Panama City and then moved by tank car across the state to Jacksonville for further distribution along the Atlantic Coast.

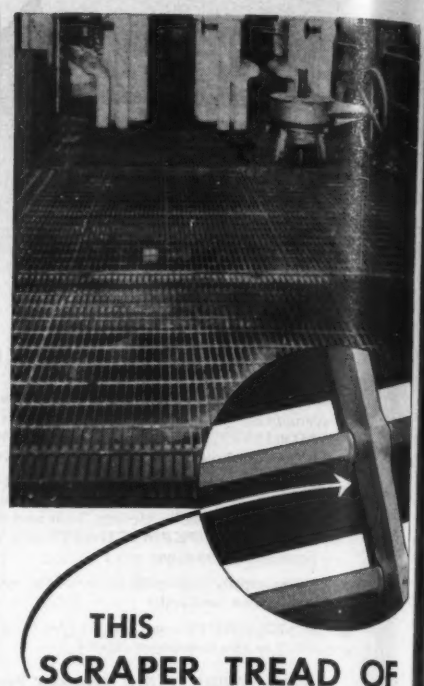
General American Tank Storage Terminals own and operate five terminals located at Houston, Corpus Christi, Carteret, Westwego and Goodhope.

Water Conditioner Company Names Distributors

American K.A.T. Corporation, 331 Madison Avenue, New York 17, New York, announces that Eimer and Amend, 633 Greenwich Street, New York, and Fisher Scientific Company, 717 Forbes Street, Pittsburgh, and also of Montreal, Canada, have taken over duistribution of their water conditioner for use in laboratory water stills.

H. K. Porter Company Names Northwest Representative

F. B. Schwartz, manager of Minnesota Pneumatic & Electric Tool Company, Minneapolis, Minnesota, has been named special representative for the Northwest for the H. K. Porter Company, Pittsburgh, Pennsylvania, com-



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prising industrial locomotives, chemical processing equipment, and all types of pumps.

A native of Shakopee, Minnesota, Schwartz attended University of Minnesota. From 1926 to 1935 he worked for Chicago Pneumatic Tool Company, becoming Chicago assistant manager. Since then he has operated Minnesota Pneumatic & Electric Tool Company, which since July occupies a new shop and office building at 2231 Riverside Avenue, Minneapolis.

Hydraulic Institute Revises Testing Code

Hydraulic Institute has announced complete revision of the test code section of its standards. This section, first published in 1936, contains specific recommendations for the testing of centrifugal and rotary pumps, both for acceptance tests in the field and in the plant of the manufacturer.

The code contains the limiting conditions for all methods of quantitative determination of capacity, head, and power input, whereby the accuracy for an acceptance test can be obtained.

Copies may be secured from Hydraulic Institute, 90 West Street, New York 6, New York, at 50 cents per copy.

Seiler Made Vice President Of Tube-Turns

John G. Seiler has been elected vice president of Tube Turns, Louisville, Kentucky, manufacturers of Tube-Turn welding fittings and flanges. He will retain his duties as sales manager of the company and continue to maintain his headquarters at the main office of the company at Louisville.

J. G. Seiler

Merit Awards

Awards of merit have been made by the government to the following companies:

Kewanee Boiler Corporation, Kewanee, Illinois, white star added to Army-Navy E pennant for continued production merit.

Keuffel & Esser, Hoboken, New Jersey, Four-Star Army-Navy E for sustained excellence in production of precision instruments for the armed forces.

Wm. Powell Company, Cincinnati, Ohio, Maritime M Burgee for outstanding performance in the production of valves for wartime activities.

Ethyl Corporation, Deepwater, New Jersey, and Baton Rouge, Louisiana, Army-Navy E for outstanding achievement in producing war equipment.

Taylor Instrument Companies, Rochester, New York, Army-Navy E for high achievement in the production of precision instruments for the armed forces.

Fisher Governor Company, Marshalltown, Iowa, Army-Navy E for outstanding production of war materials.

Cooper-Bessemer Corporation, Mount Vernon, Ohio and Grove City, Pennsylvania, Gold Star to Maritime M for meritorious war production of engines and engine-driven compressors

Gates Rubber Company, Denver, Colorado, Army-Navy E for outstanding production of war equipment.

The Bristol Company, Waterbury, Connecticut, Army-Navy E for outstanding and meritorious production of war equipment.

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HELP WANTED—Chemical Engineer for process design work on petroleum refinery gas recovery and light ends handling units. Five years experience with refinery equipment manufacturer or refiner required. Outline education, experience, draft status and salary in first letter. Reply Box 306, c/o Petroleum Refiner, Houston, Texas.

INSTRUMENT MEN—Opportunity to broaden your field of experience working on large modern new refinery to be started in near future in Gulf Coast Area. Short training program starting soon. Write or see E. D. Mattix, Cities Service Refining Corporation, 70 Pine Street, New York 5, New York.

FOR SALE—2 Belt Driven Worthington CO2 Compressors, 1200 lb., single three stage 10" x 6¼" x 3" x 18", 172 Cu. Ft. Displacement at 110 r.p.m. Subject to prior sale.

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